Cogent Food & Agriculture

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oafa20

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**To cite this article:** Hasitha Priyashantha & Janak K. Vidanarachchi (2024) Perspectives on value chain transformation towards resilient -animal-source food systems in Sri Lanka, Cogent Food & Agriculture, 10:1, 2384329, DOI: 10.1080/23311932.2024.2384329

**To link to this article:** https://doi.org/10.1080/23311932.2024.2384329



Published online: 06 Aug 2024.

COGENT FOOD & AGRICULTURE
2024, VOL. 10, NO. 1, 2384329
https://doi.org/10.1080/23311932.2024.2384329

ANIMAL HUSBANDRY & VETERINARY SCIENCE | REVIEW ARTICLE

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# Perspectives on value chain transformation towards resilient animal-source food systems in Sri Lanka

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**ABSTRACT**

Animal-source foods are crucial for a sustainable food system as they provide vital nutrients and support rural communities in their fight against poverty and food insecurity. The livestock and poultry farming industry in Sri Lanka is currently encountering numerous challenges due to the ongoing political and economic crisis, as well as the adverse effects of the COVID-19 pandemic. This has resulted in a detrimental impact on the sustainability and resilience of the animal-source food systems in the country. Hence, this article presents a comprehensive insight into the livestock and poultry industry in Sri Lanka and its ability to adapt to evolving circumstances and become increasingly resilient during times of crisis. This review underscores the significance of boosting robustness, achieving production potentials, reducing production fluctuations, and sustaining economic, social, and environmental development in rural livelihoods. Its objective is to enlighten the global readership about these advancements and prospects. Further, the article offers valuable insights into the challenges faced by the animal-source food system in Sri Lanka and recommends strategies for recovery and resilience from the author's perspective across all value chain segments. To ensure the resilience of animal-source food systems against potential external disruptions, it is crucial to establish a strong network among significant fragments of the animal-source food supply chain, provide the necessary infrastructure and institutional aid, and reinstate essential capacity building among stakeholders. Hence, discussions are relevant to a broader global audience including industry, policymakers, and academics.

**ARTICLE HISTORY**
Received 10 August 2023
Revised 18 July 2024
Accepted 18 July 2024

**KEYWORDS**
Animal-source foods; tropical livestock and poultry; sustainability; value chain analysis

**SUBJECTS**
Agriculture and food; agriculture; dairy science; meat and poultry; sustainability assessment; agriculture and related industries; sustainability

## 1. Introduction

Sri Lanka's livestock and poultry industry has a noteworthy animal-source food system that serves as an exemplary model for other developing tropical nations. It is imperative to acknowledge that the situation in Sri Lanka is unparalleled worldwide, yet, this serves as an intriguing case study for a global readership. Achieving sustainability and food security through animal-source food production is a complex challenge that demands the cooperation of public, private, and social organizations, along with efficient governance (Oosting et al., 2022). The livestock and poultry industry in Sri Lanka is currently growing, changing, and facing various challenges due to recent trends, including growing population growth and economic difficulties. Unfortunately, the industry has also experienced turbulent periods that have caused multiple unexpected shocks, such as the COVID-19 pandemic, fertilizer shortages, fuel and power deficits, foreign exchange liquidity crises, and political instability. As a result, the overall agriculture and animal-source food systems are at risk (Central Bank of Sri Lanka, 2022; United States Institute of Peace, 2022; Wikipedia, 2023). Consequently, there is a need to make changes to the current animal-source food system to create a stronger and more adaptable system for external shocks. The Sri Lankan livestock and poultry industry's reaction to unexpected and unpredictable challenges can serve as an example for the worldwide animal-source food industry. By taking a comprehensive approach to understanding the vulnerabilities of different animal-source food systems and their ability to recover from a crisis, the global animal-source food industry can learn valuable lessons.

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Over the recent years, as Sri Lanka was almost self-sufficient in egg and chicken meat production, the domestic consumption requirements were largely met through domestic production, while the industry was advancing as a promising venture for the export market (Alahakoon et al., 2016; The Poultry Site, 2014). The shortage and high cost of feed materials caused production issues, resulting in a lack of animal proteins. This posed a threat to the country's food security. Only 40–41% of the milk needed is supplied by the Sri Lankan dairy industry, with the remainder being imported from other nations (Priyashantha & Vidanarachchi, 2021). Figure 1 shows that Sri Lanka imports of animal-source food from different international markets to meet the supply and demand gap. This high import dependency makes the country vulnerable to fluctuations in international trading conditions. It also highlights the fact that Sri Lanka is far from being self-sufficient in certain animal-source foods. Therefore, the focus of future animal-source food system transformations should be on achieving sustainability and food security by enhancing animal-source food production within the country. Animal-source foods contain a significant amount of bioavailable nutrients that can play a vital role in establishing food and nutrition security (Beal et al., 2023). Moreover, animal-source products are essential in maximizing various ecological conditions and have the ability to adapt to different cultural practices, thereby promoting the well-being of agricultural communities. The study aimed to comprehensively assess and propose strategies for enhancing the resilience of Sri Lanka's livestock and poultry value chain. The research focused on four main components: primary production, secondary processing, marketing, and consumption. The overarching objective was to identify challenges and opportunities within each component and propose integrated measures to build a more resilient animal-source food system.

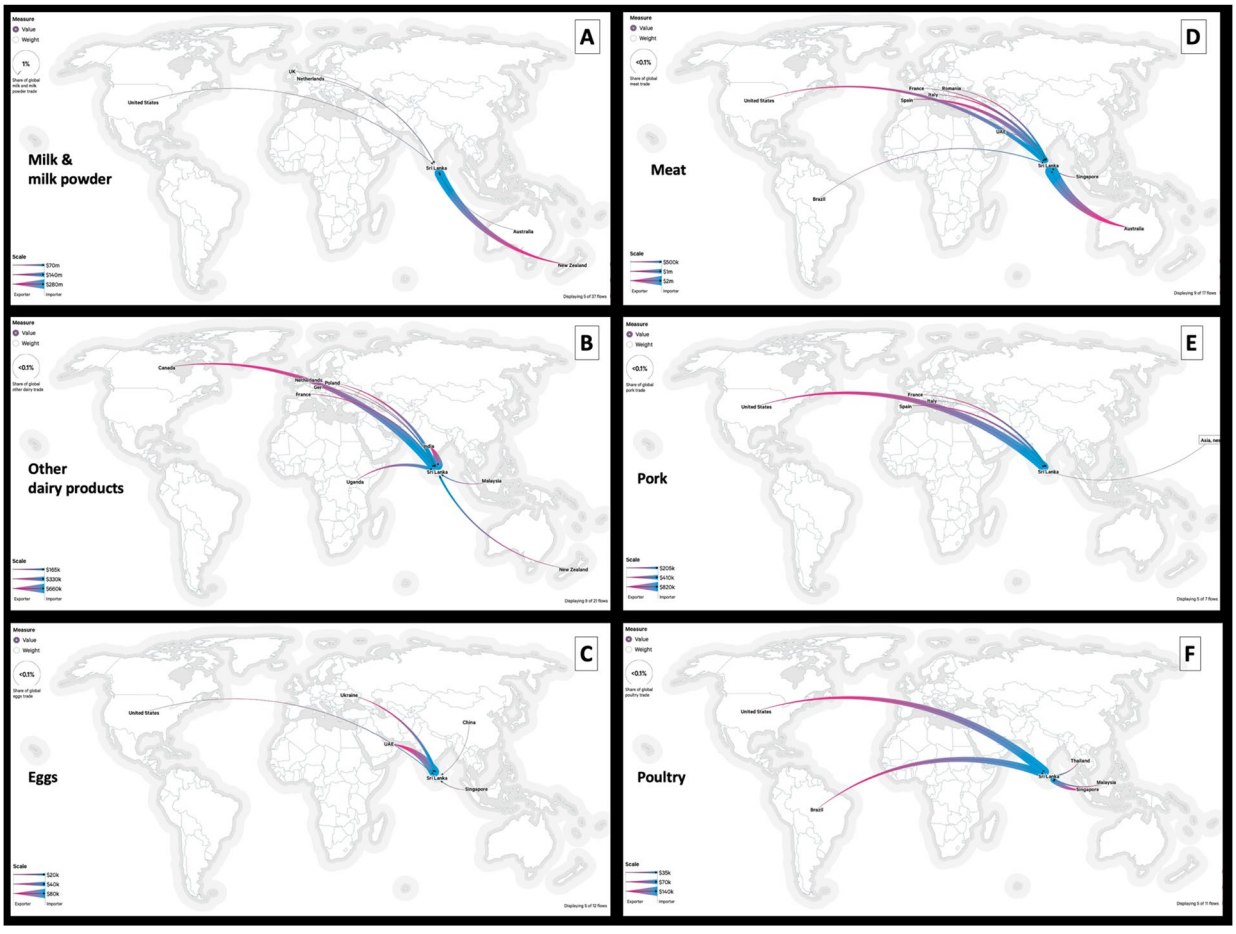


**Figure 1.** Map showcasing the origin of imported animal-source food products to Sri Lanka in 2020 (the most recent available data). (A) Milk and milk powders, (B) Other dairy products, (C) Eggs, (D) Meat (combination of lamb, pork, beef, chicken), (E) Pork, (F) Poultry. Import line thickness is based on the value of the commodity. *Source*: Resource Trade Earth, Chatham House (2021), 'resourcetrade.earth', https://resourcetrade.earth/.

## 2. Materials and methods

### 2.1. Sampling methods and data collection

A literature review was performed to address the current study's objective. The relevant articles and reports were searched on various scientific databases like Google Scholar, ScienceDirect, JSTOR, Web of Science, Scopus etc., by using keywords. The information included a comprehensive analysis of key value chain segments, focusing on primary production, secondary processing, marketing, and consumption analyses to develop a holistic understanding of the challenges and opportunities within Sri Lanka's livestock and poultry value chains. Country-specific data on primary production status, raw material import quantities, policies related to feed ingredients and constraints and opportunities for livestock and poultry development were gathered from the Central Bank Reports Sri Lanka, Department of Animal Production and Health (DAPH) Annual Reports, Department of Census and Statistics Sri Lanka, Sri Lanka Customs and Livestock Outlook of Sri Lanka. Key stakeholder interviews, including representatives from the Ministries, Department of Animal Production and Health, Sri Lanka, National Livestock Development Board (NLDB) and industry experts, offered qualitative data on breeding material and feed supply challenges. Expert opinions gathered through personal consultations allowed for a comprehensive understanding of raw material supply dynamics and informed recommendations for enhancing resilience in the value chain. Secondary data on processing aspects of livestock and poultry were obtained from reports and articles as referred to within the article and through consultation of concerned stakeholders in public and private institutions, with a focus on the manufacturing of common animal-source food products in Sri Lanka, such as liquid milk products, yoghurt, fermented buffalo milk gels (*Meekiri*) ice cream and meat products. Existing facilities, their distribution, and the efficiency of processing were assessed. Marketing data encompassed the market fluctuations, demand elasticity, and the impact of digitalization on animal-source food value chains. Price inelasticity and the need for educational marketing strategies were identified. Consumption patterns were analyzed based on changing family incomes, urbanization, and globalization trends. Import dependency challenges, myths, and misconceptions surrounding animal-source foods were identified. Global best practices in livestock and poultry value chains, especially in developing tropical nations, were also conducted using the aforementioned databases. Successful strategies employed by other countries to address similar challenges and enhance resilience in the face of crises were assessed and reported.

### 2.2. Analysis

Analysis of the primary production component involved assessing the contribution of the animal production sector to the Gross Domestic Product (GDP), identifying obstacles to resilience, and proposing strategies for improving productivity. Quantitative data, including import quantities, local production statistics, and market values, were analysed to identify trends and variations.

Qualitative data underwent thematic content analysis, revealing recurring challenges and patterns in breeding material and feed supply. Comparative analysis was employed to assess the impact of inconsistent government policies and import tariffs on the feed industry. Secondary processing data analysis included the identification of value-added products, challenges in the secondary processing step, and suggestions for improving efficiency. Consideration was given to regional distribution and potential collaborations to bridge gaps in processing capabilities. The analysis involved the marketing data to understand the market dynamics, the impact of global demand, and the role of educational marketing in stabilizing prices. The consumption analysis focused on understanding the evolving consumption patterns, the role of consumers in the value chain, and the challenges posed by import dependency. The impact of consumer perceptions and awareness on food safety and quality was assessed.

### 2.3. Recommendations

The recommendations for the raw material supply section encompass the need for strategic planning and execution. Based on the analysis of primary production data, recommendations were formulated. Proposals were made based on secondary processing analysis, marketing data and consumption data. Suggestions were also made to focus on eliminating redundancies and implementing missing components in the value chain for sustainable and resilient transformation. The study acknowledged limitations, such as data availability constraints, in marketing and consumption analyses. Recommendations for future research were suggested to refine strategies and

improve the overall resilience of Sri Lanka's livestock and poultry value chains.

## 3. Livestock and poultry value chain segments

The value chains in the Sri Lankan livestock and poultry sector can be divided into five segments according to Figure 2: (i) raw material supply, (ii) primary production, (iii) secondary processing, (iv) marketing, and (v) consumption. To effectively support small and medium-sized livestock and poultry entrepreneurs with secure and sustainable job opportunities, it is imperative to assess the individual value chain segments and their potential in each sector. When evaluating the value chain and its capacity to withstand challenges, to gain a comprehensive understanding of its overall resilience, it is vital to consider gender inclusivity, environmental impact, and the welfare of livestock and poultry, as well as the knowledge, skills and entrepreneurship abilities of the farming community (Barua et al., 2021; Bukachi et al., 2023; Godde et al., 2021). Consequently, key players and participatory stakeholders will also be assessed to understand the resilience situation of the value chain in each of those five key segments. Reviewing the holistic view of the livestock and poultry system in Sri Lanka will generate scientifically valid arguments and futuristic perspectives for any food system under a similar context. Moreover, this will provide an in-depth understanding and perspectives to achieve sustainable global animal-source food systems in the future.

Compared to 2021, the livestock and poultry sector in Sri Lanka is currently experiencing a decline in 2022, where national milk, egg and poultry production has reduced by 1.3%, 5.4% and 3.7%, respectively (Central Bank of Sri Lanka, 2022). Due to the challenges and production shortages that the sector is currently facing, we must gain a better comprehension of the current status and future direction of the livestock and poultry value chain. Thus, the authors provide their perspectives on how the livestock and poultry industry in Sri Lanka can contribute to sustainable economic growth, inclusive social development, and efficient use of natural resources within each value chain segment.

### 3.1. Raw material supply

In order to establish a robust and reliable animal-source food system, it is crucial to have a steady and effective supply of raw materials for livestock and poultry farming. Livestock and poultry rearing is the primary source of income for rural farming communities, where the success of farming relies on the quality and quantity of inputs provided to this sector (ILRI, 2011). Access to high-quality breeding material is crucial for producing high-quality products that can withstand local conditions. Availability and accessibility of this material are key factors to ensuring success. In Sri Lanka, the livestock sub-sectors,

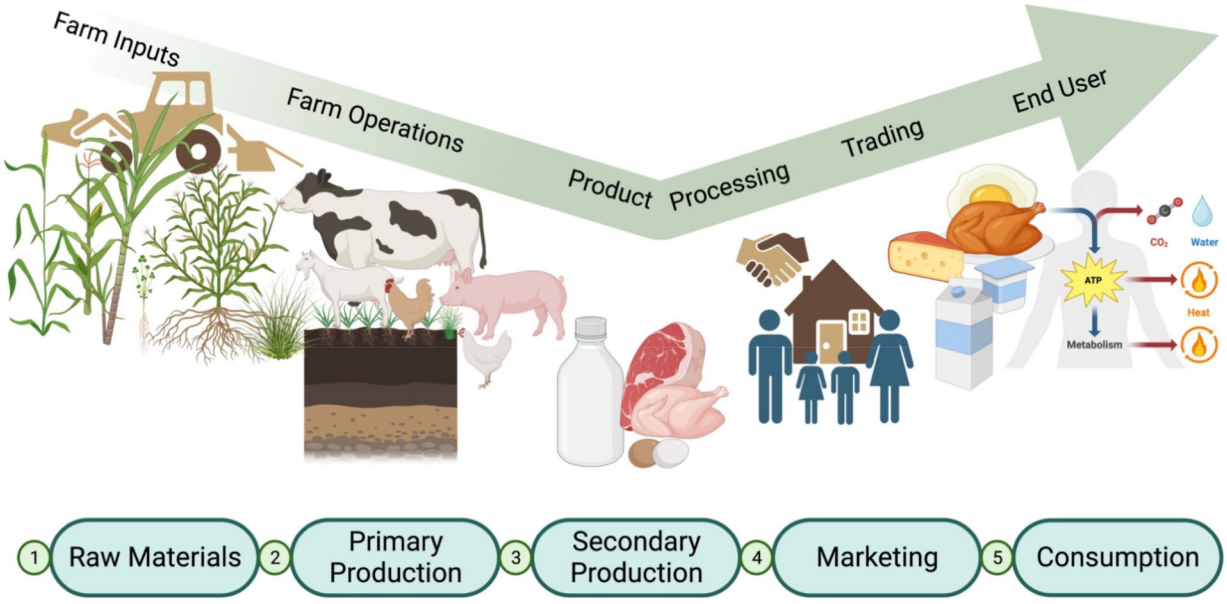


**Figure 2.** Livestock and poultry value chain segments in Sri Lanka; (1) raw material supply, (2) primary production, (3) secondary processing, (4) marketing, and (5) consumption.

particularly cattle, buffalo, and goat, have diversified by using locally adapted breeds and types that match the available resources to produce high-quality final products with desirable characteristics (Weerasingha et al., 2022). Poultry farming heavily relies on genetically superior chicken strains, which are usually imported from other countries. Currently, there is a significant problem concerning the availability of layer-parent chickens and broiler-parent chickens. Small-scale farmers are being forced to sell or cull their valuable breeding stocks due to the increasing costs of feed and the lack of other essential resources, where this issue was particularly prevalent in the layer chicken sector. As a consequence, the current supply of breeding materials, grandparent and parent stocks falls short, leading to elevated costs of table eggs and broiler chicken meat.

In the author's opinion, upon closely reviewing the available information, the attempt to import dairy cattle breeding animals from Australia and New Zealand to Sri Lanka's dairy sector was a total failure. A company was contracted to import 20,000 dairy cows under the deal. However, only about 5,000 animals were imported. The failure of the project was a result of poor planning and inadequate knowledge and technical know-how among farmers. This made imported dairy animals vulnerable to diseases and led to low milk yield and poor conception rates, which ultimately resulted in the project's failure (ABC News, 2019; Daily Mirror, 2024). The Department of Animal Production and Health maintains Goat Breeding Centers in Thelahera, located in the Kurunegala district, and Imbulandanda in the Matale district. They discovered some health issues in the breeding stocks imported from Australia, specifically the presence of bluetongue disease, recently (personal communication).

The animal feed industry in Sri Lanka is quite advanced. Most of the poultry feed needed in the country is produced locally. As per the Department of Animal Production and Health (DAPH), the market for concentrate feed producers comprises twelve large-scale producers, namely Ceylon Grain Elevators, CIC Feeds, New Anthoney's Feeds (previously known as Gold Coin), New Hope Lanka, Fortune Agro Industries, Pussalla Feed, Mahaweli Feed Mills, Profeed (Pvt) Ltd., Kosmo Feed Mills, Empire Feed Mills, Weehena Animal Nutrition and New Bernards Animal Feeds and Super Feed. Furthermore, there are 50–54 medium and small-scale producers, along with 45 small-scale producers registered with DAPH (Priyankarage, 2020). There are significant challenges to be addressed concerning forex and the quota system in place for maize imports. Unfortunately, the limit is set at a mere 225,000 MT per year which poses a considerable challenge with deficiencies in quantities needed for producing animals. Additionally, the inconsistent government policies and very high import tariffs for feed ingredients are presenting further difficulties that need to be resolved.

The feed industry for ruminants is currently stagnant. Ruminants primarily rely on naturally grown forages, which can be found in areas such as natural grasslands, roadsides, marginal lands, paddy bunds, homegardens, fallow paddy fields, and coconut lands (Premarathne & Samarasinghe, 2020). Encouraging the cultivation of forages as a crop and providing incentives and training on how to grow them is the key solution to address feed vulnerability. It is noteworthy that there is little tradition of cultivating large-scale forages in Sri Lanka, as livestock farming is mostly done at a subsistence level with a few exceptions. Enhancing the availability of quality pasture, fodder, and concentrate feeds can significantly improve the sustainability of the livestock and poultry sector, thereby improving animal nutrition and promoting farming practices. It is crucial to prevent sudden changes in feed quality, and one way to achieve this is by motivating private sector organizations to produce high-quality silage through forage production and conservation. This will strengthen the production aspect of the livestock and poultry value chain as well as ensure the consistent availability of raw materials for animal feed. To further facilitate these initiatives government should have a clear policy on the easy availability of high-quality forage seeds and planting material within the country. At the moment there are many bureaucratic procedures that hinder the importation of quality forage seeds and planting material; e.g. Mulato II hybrid (*Brachiaria ruziziensis* × *B. decumbens* × *B. brizantha*), Tifton 85 Bermudagrass, Fodder maize etc. (Burton et al., 1993; Pizarro et al., 2013). Without these high-quality forages, the optimal development of the dairy industry is challenging. Additionally, passing know-how to forage cultivators on technically logical agronomical practices including planning, and accomplishing optimal harvesting characteristics by cutting and gathering the forages at their optimum nutritious stage would be of utmost importance.

The livestock and poultry industry in Sri Lanka relies heavily on imported feed ingredients. In 2021, the country imported various feed ingredients including maize, wheat, cereal brans, oil cakes, meat and bone meal and fish meal, with a combined value of 94 million USD. This represents an increase from 59

million USD worth of imports in 2020 (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2021a). According to the Central Bank Report 2022, during the first half of the year, the livestock sector observed a subdued performance as the progress in the sector was hampered by inadequate feed materials, both imported and domestically produced, together with the cost of production escalation, thereby pressurizing domestic retail prices to record highs. This observed increase in feed cost can be partly explained as a fact of decreasing the value of local currency against USD, an increase in global market prices and an increased amount of importations (imported quantities in 2020 is 247,728 MT, 2021 is 269,162 MT). The increased feed cost affected the farm gate price and profit margin of primary producers while diminishing the buying power of the general consumers as the unit price of the final product has been subjected to increase over the years.

Since feed accounts for one of the major costs (~80%) in animal farming, some livestock and poultry farmers are compelled to produce their own feed (self-mixing) at their convenience. Yet, the supply of locally sourced raw materials is limited and improvement strategies to enhance the nutrient digestibility and availability of the existing locally available feed materials and by-products are essential. Additionally, to secure the continuous supply of high-quality feed materials, farmers need to be trained on Good Agricultural Practices (GAP) and strategies for conserving the forages and preserving the surplus for the dry season. Additionally, adopting such practices will provide economic, social and environmental improvements in the value chain, such as an increase in return on investments, generating higher production, and continuing employment (Mandarino et al., 2019). Further, it is necessary to commercialize hay and baled silage production systems to overcome feed scarcity issues in the urban areas to make feed available throughout the year for continued and uninterrupted production. In establishing a resilient food system, a shortage of feed raw materials for compound and concentrate feed production is another foremost restraint to livestock and poultry production systems (Silva & Dematawewa, 2020). To address challenges in livestock production due to resource scarcity, repurposing food losses like former food products and bakery by-products as alternative feed for pigs and ruminants is a promising solution. Despite initial hesitations, both repurposed food items exhibit significant nutritional value, pose low health risks, and do not hinder animal growth when included in complete feed. Embracing alternative feed sources, especially in the face of rising costs and ingredient shortages, is crucial. This approach not only mitigates feed scarcity but also reduces the environmental impact of animal products. The key to success lies in active participation from feed and food processors, alongside stakeholders, to maximize the benefits across the food and feed chain (Pinotti et al., 2021). It is also important to upsurge and introduce precise feed formulation and precision feed management concepts to enhance feed utilization efficiency (Chase & Fortina, 2023).

In addition, the authors propose the use of some advanced and novel trends detailed elsewhere (Berkhout, 2022), such as (i) use of functional complementary feeds that use synthetic amino acids, exogenous enzymes, medium chain fatty acids, oligo- or polysaccharides, and polyphenolic acids, (ii) optimising compound or concentrate feeds for nitrogen and phosphorus, by promoting precise feeding of proteins to provide required types and amounts of digestible amino acids, (iii) alternative non-genetically modified organism (GMO) protein sources need to be used as this has become a real challenge with soybean meal because most of the soybean is GMO-originated. Hence, there are trends to use non-GMO rapeseed meal, field beans, peas, lupins or sunflower meal, (iv) use of unconventional protein sources such as insect (e.g. black soldier fly larvae) meal as alternatives to soybean meal and fish meal.

Finally, eliminating inconsistent government policies on the national customs import tariff is essential, since the government is changing policies without proper progress monitoring and need assessments that would directly and significantly impact the feed industry. By adopting above discussed raw materials perspectives, a resilience system can be built through the efficient use of natural and available resources to create sustained economic and social development.

### 3.2. Primary production

Primary production in an animal-source food system includes livestock and poultry husbandry and similar practices that yield raw food materials. This also encompasses activities within the point of origin such as milking, harvesting, on-farm storage, and handling practices (Commission for Environmental Cooperation, n.d.). In 2022, the percentage contribution of the animal production sector to the GDP of Sri Lanka was reported as 0.7% according to the Central Bank Report (Central Bank of Sri Lanka, 2022). An important obstacle towards creating resilient food systems is

the currently available low-efficient primary production systems in the Sri Lankan livestock and poultry sector. Thus, strategies and actions should be taken to promote methodologies for increasing productivity at the farm level through improving feed intake and feeding frequencies, and efficient feed management (low feed conversion rates) while reducing feed wastage and providing quality water adequately using management-intensive systems. For this purpose, local farmers may adopt precision feed management aspects according to the growth and development stages (phase feeding) to provide an optimal plane of nutrition by maximizing the utilization of available natural resources, as feed is scarce and costly (Chase & Fortina, 2023).

Existing livestock resources in the farm also play a vital role in upkeeping the productivity of the farm and building the resilience of the system, monitoring and evaluation of breeding programs should be implemented to facilitate the keeping of the genetic potential and well-managed follower or replacement stock within the farm. For dairy farms, to ensure sustained milk production, breeding programs are a must (Shamsuddoha et al., 2023) and therefore, it is advisable to provide male breeding animals appropriately for agro-climatological regions/species/pure breeds and crosses whenever necessary within differing animal-source food systems. This is further can be achieved by improving the efficiency of effective artificial insemination services through capacity building and resource intensification. Moreover, for such farms improved genotypes should be systematically introduced based on a thorough investigation of the necessity of the industry/sector and breeding policy of Sri Lanka. This adaptation of suitable breeds will enable us to acclimatize to changing climatic conditions as well as market situations, both from input and output perspectives. If proper animal resources are absent in the farm, in combination with other external and internal factors, output at the primary production level may diminish. As an example, In 2022 domestic milk production in Sri Lanka has been recorded as 380 million litres, where a decline of 7.78% has been observed compared to 2021 (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2022). Thus, highlighting the importance of adopting precautions and recommendations as detailed in this article to build up resilience.

At the primary production level, several activities might lead to the loss of raw materials and their quality, i.e. pest & diseases, non-availability of fertilizer for forages, adverse weather conditions, lack of proper storage facilities for farm produces and products, and market variabilities-related issues (Commission for Environmental Cooperation, n.d.). Such scenarios may also affect Sri Lankan animal-source food sector hindering its pathway towards building a resilient food system. Thus, strategies and adaptations must be created and presented to vulnerable farming communities to empower their primary production systems, without being impacted by external uncertainties. Another strategy to create more resilient farms is to establish a dedicated extension service for the livestock & poultry sector that will deliver up-to-date knowledge on changing conditions and strategies for adapting to such scenarios. Since small-scale farmers are more vulnerable compared to large or medium-scale operators, participatory opportunities for small-holder farmers must be created to engage in effective extension and training programs to improve their skills in facing uncertainties in the value chain.

As stated above, quality, safe and adequate supply of feed is one of the most important aspects of the livestock and poultry value chain. Hence, strategies and infrastructure must be in place at the farm level to store when surplus is available and therefore, feed storage facilities should be constructed within farm units as well as facilities should be developed to avoid contaminations from fungal toxins. In addition to creating storage and infrastructure, providing high-quality water is essential to any livestock or poultry species. Therefore, the farm unit must create infrastructure for providing adequate and high-quality drinking water for 24 h as this is often neglected mainly by dairy farmers on a small scale as cows or buffaloes are free ranging. Thus, at the farm level focus should be given to establishing possible water conservation strategies and facilities to face the dry season, when water is scarce.

In small-scale farming communities, often farmers can not afford expensive and sophisticated machinery to facilitate their work. Thus, to promote the use of novel and advanced use of technologies in primary production, farmers should be provided with new tools and machinery for use in farming practices related to livestock and poultry sectors at concessionary rates. If such procurements are not affordable, farm communities should form an interest group with farmer-led volunteer organizations and source such advanced machinery based on a participatory approach (farm village concept) to be used within the community.

A unique competitive advantage in the primary production of Sri Lankan livestock and agriculture

context is the diversity of the geographical and agro-ecological regions. This offers the possibility to adapt several types of farming systems that enhance the resilience of the livestock and poultry sector, rather than confining to the same farming system island-wide. In Sri Lanka, animal-crop mixed farming systems can be observed on dry lowlands either as extensive or semi-intensive management systems (Vithanage et al., 2013). In such systems, cattle/buffalo, goat and poultry are reared in combination with paddy and other field crops. Moreover, cattle/buffalo and small ruminants such as goats and sheep are important capital assets for peasant farmers in dry lowland areas (Ibrahim et al., 1999). Such farming systems offer the farmers resilience under external shocks as the reliance on monoculture farming is limited and offers the wider flexibility to adopt uncertainties. The dependency on external inputs may vary with the type of farming system, where it leads to lesser resilience when the farming system is highly dependent on external inputs. Often, in such livestock farming systems, low production performances and the frequent incidence of diseases are observed (Vithanage et al., 2013), which leads to lowering productivity and increasing the vulnerability of the system. Hence, coordinated and well-planned integration of system performances and activities are necessary to improve the sustainability of farming livelihoods in crop-livestock integrated farming systems to provide more resilience in food systems in Sri Lanka as illustrated in Figure 3. This will enable empowering and uplifting the living standards and economic viability of the farming communities through improved farm performances and production while creating a resilient food systems.

Additionally, the livestock and poultry sector in Sri Lanka is currently lacking specialized and young farmers and sees them as entrepreneurs rather than traditional peasant farmers. Although the involvement of women in livestock production, especially in small-scale dairy farming can be observed in some locations, empowerment programs must be performed to encourage the involvement of women in the livestock and poultry sector to build resilience

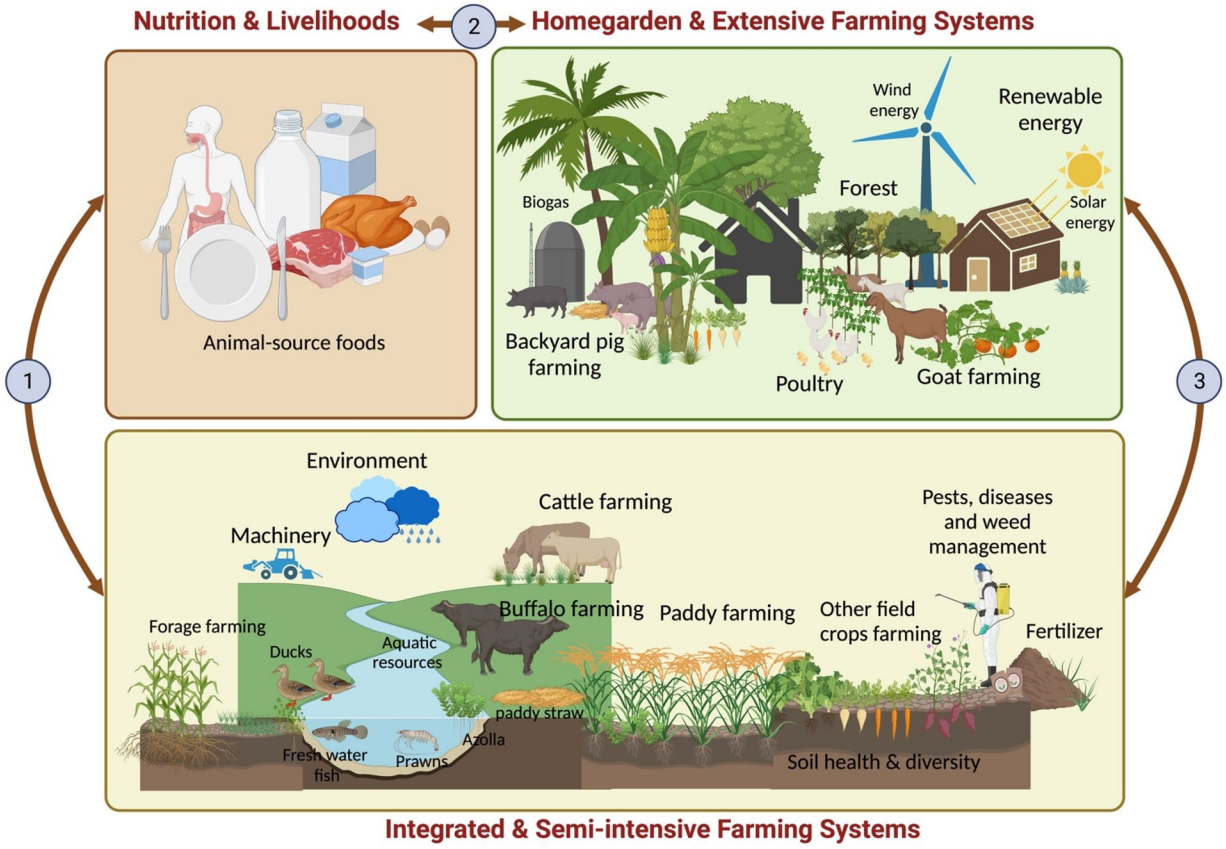


**Figure 3.** Schematic representation of a proposed resilient farming system with their interactions in a primary production system with farming livelihoods to supply animal-source foods.1. Interactions between integrated & semi-intensive farming systems and nutrition & livelihoods of the farming community; 2. Interactions between nutrition & livelihoods of the farming community and homegarden & extensive farming systems; 3. Interactions between homegardens & extensive farming systems and integrated & semi-intensive farming systems.

and sustained livelihood. Local authorities must provide necessary aid and support to improve farming practices and minimize the vulnerability towards various external uncertainties in farming. Finally, at the farm level, strategies should be created to establish manure disposal and treatment facilities to efficiently utilize the available manure as a soil amendment or biogas production. This will enable to combat two key major crises that peasant farmers in Sri Lanka currently experience, e.g. high prices and shortages of fertilizers and electricity. Thus, skill and knowledge enhancement programs in this aspect would merit the goals of creating sustainable and resilient food systems through sustained economic growth, inclusive social development and efficient use of natural resources at the primary production level.

### 3.3. Secondary processing

At this secondary processing step in the animal-source food systems, the focus lies on collecting raw materials from primary producers and further processing them into the final product. If the raw material is milk, then secondary processing in the Sri Lankan context includes the manufacturing of fluid milk, fermented gels (i.e. set-yoghurt, drinking yoghurt and curd/*Meekri*), ice cream, milk powder, butter, ghee and cheese (Figure 4). Often these manufacturing units are not spread evenly or closely with the geographical distribution of farms. Therefore, the transportation of raw materials to secondary processing plants is vital. When regional milk chilling centres are not available nearby facilities should be created for the storage and cooling of milk for small farmer cooperatives, i.e. only 293 milk chilling centres are available islandwide (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2022) to cater to 318,512 dairy farmers (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2021a). On some occasions, secondary processing may also happen near the primary production and therefore, eliminate the need for prompt


**Figure 4.** Dairy value chain focusing on secondary processing of commonly market available dairy products in Sri Lanka. (A) Cattle farm, (B) buffalo farm, (C) milking, (D) milk collecting bucket, (F) small-scale farmers submitting their milk to collecting centres, (G) transport of milk, (H) performing platform test for judging milk quality, (I) milk chilling, (J) storage, (K) processing, (L) fermenting of buffalo milk in clay pots, (M) cheesemaking, (N) *Meekiri*/fermented buffalo milk final product, (O) cheese, (P) liquid milk, (Q) set-yoghurt, (R) drinking yoghurt, (S) ice-cream, and (T) milk powder.

transportation. Such an example is traditional fermented buffalo milk gel, also known as *Meekiri* is produced near the buffalo farming systems and thus secondary processing, i.e. value addition, is performed on location in most cases (Adikari et al. 2021; Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2022; Priyashantha et al. 2021; Shamsuddoha et al., 2023). This creates more resilience in the farming system as it eliminates the uncertainties on the variability of the market with a clear connection between primary and secondary steps in the value chain. It is also equally important to upgrade the existing facilities to improve the efficiency and effectiveness of processing animal-source products to improve the productivity of the system. If such available technologies are lacking, coordinated and monitored external collaborations can fill the gaps.

If the raw materials are meat, secondary processing will include various value-added products, which will broaden the profit margin. In the case of eggs, secondary processing will be minimal, except for powdered eggs or liquid eggs, in addition to several value-additional activities related to the packaging and handling of raw eggs. Overall, value addition (new product development or improvement) of existing products should be in focused in the secondary processing to improve the quality and safety of animal-source foods. Thus, secondary processing activities in animal-source food value chains are a crucial connective interface between the primary producer and end user. Therefore, in establishing resilience in the value chain, secondary processing plays arguably an equal role in sustaining economic and social growth.

### 3.4. Marketing

Marketing of animal-source foods, which aid in flowing the final product towards consumers, is an essential step in building resilience as the flow of materials ensures the sustenance of the value chain. A properly organized and communicated animal-source food value chain can be used to deliver nutritious and safe foods to target groups, through novel formulations and processing strategies (Mills et al., 2007). In recent years, the Sri Lankan market in the animal-source food sector has experienced numerous fluctuations and therefore, strategies should be presented to reduce the uncertainty in market conditions and prices. In Sri Lanka, demand for animal-source food is price inelastic, where there is a higher degree of substitutability between chicken, beef, pork, chevon, eggs, and fish (Rathnayaka et al., 2021). Properly planned educational marketing strategies will be helpful in rectifying the issues related to the value chain with proper and balanced communication. Digitalization of the market and the use of modern e-technologies are key to connecting the broken value chain far and wide (Shahadat et al., 2023). In order to expand the value chain towards the global market, value addition and adherence to international quality and safety standards are required. This will achieve diversified market opportunities and create more resilences.

As a result of amplified demand for milk, at the time of shortages in importations and availability of domestic milk powder, the price of milk powder significantly increased and farmers received a relatively high price for locally produced liquid milk during this crisis period in 2022 (Central Bank of Sri Lanka, 2022). In 2022, the average farm-gate price per litre of cow milk was around 115.23 LKR/L (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2022) (1 LKR = 0.0031 EUR), where as in 2023 it has reached to 160–165 LKR/L (market observations by authors) and therefore, farmers on a small-scale should be trained both socially and professionally to add value to their raw material and communicate it to the local market with a value orientation. This will also enable creating entrepreneurs, by adding value and services to their products to strengthen market competitiveness. Youth farmers should, therefore, aim at differentiation, value addition, branding, and increasing the quality & safety of animal-source products while adopting climate-smart practices. Thus, it's essential to reconnect the fragmented value chains and improve market linkages to promote value chain integration to reach economic and social development.

### 3.5. Consumption

At present consumption patterns of animal-source food are changing in Asia, due to rising family incomes, urbanization, globalization, and modernization of marketing infrastructure (Rathnayaka et al., 2021). The role of consumers in the animal-source food value chain is important for various reasons. The consumption of animal-source food varies with the economic status of the households, as animal proteins are relatively expensive and cannot be afforded by low-income households. In Sri Lankan context, consumption patterns were affected as the price of animal-source foods escalated due to increased price of feed and other input supply, fuel shortages, forex issues, and electricity crisis. Often

consumer perceptions and attitudes about the safety of animal-source food influence the choice and consumption of animal-source foods (Bukachi et al., 2021). As the urban western population is perceiving animal farming as an unhealthy, unsustainable, and unethical practice, more consumers are reducing the consumption of animal-source foods. This trend is slowly melting into Sri Lankan consumer perceptions and attitudes as well. Yet, consumers can get outraged benefits by consuming animal proteins and safeguarding food security, nutritional security (prevent malnutrition), ecological function and livelihoods associated with fragile animal-source food value chains (Leroy et al., 2022).

Consumption of various dairy products in daily life is a vital component of an average Sri Lankan lifestyle (Priyashantha & Vidanarachchi, 2021). The per capita availability of common livestock and poultry products as the percentage change over 2021 and 2022 is presented in Figure 5. The per capita availability of milk and milk product has been negative, where it has reduced to 48.69 L/year in 2021 from 52.81 L/year in 2020 (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2021b). This trend has continued to 2022 as well, where in 2022 per capita availability of milk was 34.76 L/year (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2022). Sri Lanka is dependent on milk powder and dairy products importation, where the importation of dairy products in 2022 was 53,797.85 MT which is a decrease of 39.19% compared to 88,481.83 MT in 2021 (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2022). This is partially explained by government policies and market-driven scenarios in Sri Lanka. However, due to high consumption demand and a limited supply of fresh milk, producers mainly import milk powder from abroad and reconstitute it into liquid milk to sell for the local market as well as the processing products such as yoghurt. Chicken meat price has doubled in the Sri Lankan market in 2022 compared to 2021. Moreover, in 2022, 171.15 MT of poultry meat and meat products, 244.32 MT of pork and pork products and 54.02 MT of liquid egg were imported to Sri Lanka (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2022). These importations suggest that the country's higher dependency on exported food items and therefore, challenges the resilience of the existing food value chains that are origin from local and small-scale livestock and poultry sectors.

Additionally, the prevalence of myths and misconceptions about animal-source foods among Sri Lankan consumers negatively influences consumption and thereby impacts the nutrient/animal protein intake

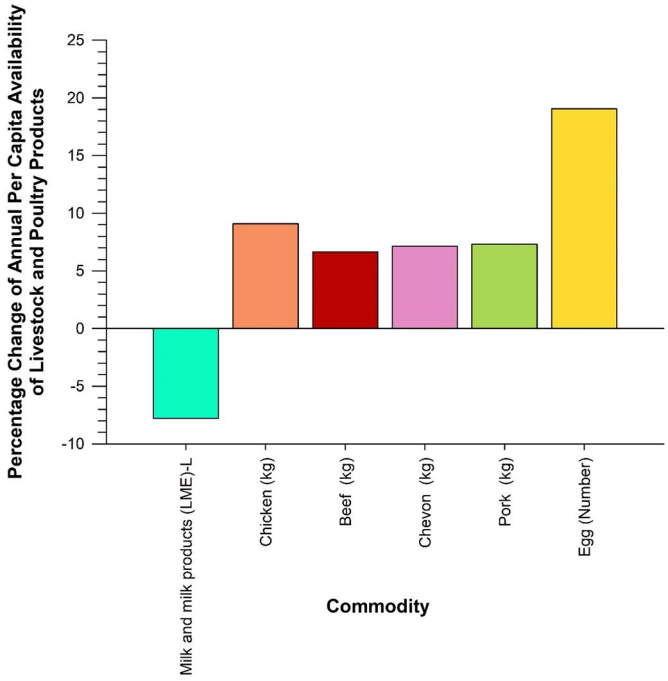


**Figure 5.** Percentage change of annual per capita availability of livestock and poultry products in Sri Lanka in 2022 compared to 2021. Data source: Livestock Outlook of Sri Lanka (2020 and 2021) (Department of Animal Production and Health, Gatambe, Peradeniya, Sri Lanka, 2021b).

(Atapattu & Wimalarathne, 2018; The Sundaytimes Sri Lanka, 2014). This impends the sustainability and resilience of the animal-source food value chain and creates a gap in the consumption and supply of animal protein for human nutrition. In this scenario, food nutritionists and educationists' role is important to communicate to the general public regarding the benefits of consuming animal proteins by breaking the existing myths and misconceptions. These communications and discussions should encourage and lead a dialogue among policymakers to create nationwide consensus on the consumption requirement of animal-source foods. For achieving this task, the role of media (mass and social) needs to be highly acknowledged. Another important misconception is associated with culling, which is the elimination of undesirable livestock due to uneconomic reasons such as being unproductive, diseases, etc. part of the standard practices in livestock herd management. Yet, the decision on culling is complex with multidimensional aspects with an important influence on the economic performance of the dairy industry (Monti et al., 1999). However, culling cows from dairy farming, i.e., slaughtering cattle is banned in Sri Lanka and therefore, a balanced and science-based approach must be made to reduce the enormous impact on the economic performances of the dairy industry while attracting local and foreign investors.

Hygiene of animal-source food is of utmost importance but often may be compromised in small-scale productions. The poor understanding and awareness of consumers, as well as producers on hygienic-sanitary control requirements of animal-source foods during the production process, may impair the purchasing decisions (Nespolo, 2021). Subsequently, exposing such consumer groups to the risk of acquiring potential zoonotic diseases. Thus highlighting the importance of the involvement of multi-stakeholders in creating a safer animal-source food value chain. Consequently, the quality and safety of animal-source foods play an important role in the value chain of animal-source foods (e.g. consumption) and thereby establishing resilience in the system. However, several potential food fraud actions (e.g. substitution, adulteration, counterfeiting, mislabeling, etc.) on animal-source foods may impair the sustenance and resilience of the animal-source food value chain. Fraudulent animal-source foods can happen in natural or accidental circumstances. As a result of cross-contamination, the presence of an unintended allergen in non-allergenic foods may pose serious health risks to consumers (Visciano & Schirone, 2021). Thus, the consumption and manufacture of animal-source foods in the Sri Lankan market should be cautiously performed to avoid any such circumstances. Advancing applications connected to various rapid and non-destructive analytical tools along with data analysis methods have enabled the identification of authenticity and avoid food fraud in animal-source foods (Hassoun et al., 2020). Therefore, an efficient food safety management system that encompasses the safety and quality of animal-source food by defencing the food items and avoiding any fraud is essential. Moreover, the need for proactive procedures and implementation of proper safety regulatory actions within food production lines will ensure the confidence of consumers regarding the quality of the final product. Hence, establishing a hazard analysis and critical control points (HACCP) and food safety/quality management systems within the production and processing of animal-source foods will fight against the occurrence of food safety risks associated with the consumption of animal-source foods (Awuchi, 2023).

The traceability of animal-source products is of utmost importance to enhance confidence among consumers. This is because, consumers' buying behaviour and product preferences are associated with certified traceability and credibility, where consumers are interested in guaranteeing the reliable origin of the product (Magalhaes et al., 2021). Therefore, Sri Lankan livestock and poultry sector must adopt a proper traceability program using appropriate traceability technologies (e.g. Rapid Alert System for Food and Feed) for farm animals and their products to upgrade consumer confidence. Additionally, to achieve this, it's important to review the existing and outdated legislation, e.g. Food Act, No. 26 of 1980 (FCS LANKA, 1980) and strengthen the involvement of the Sri Lanka Standards Institution to protect the consumers. For this purpose, laws need to be enforced and regular inspections need to be made to ensure the safety and quality of the whole value chain (i.e. producers, storage/transporters, processors, traders, and retailers), in addition to creating traceability. Therefore, in an effort to increase consumers' preferences for safer animal-source products, the relevant multi-stakeholders need to execute the practice of traceability systems in the whole animal-source food value chain.

## 4. Remarks

The complexity and wicked nature of the supply chain vary depending on multiple factors involved in the production of the final product from its raw material. Comprehensive agricultural research work and


**Figure 6.** Graphical summary of recommendations suggested in Agricultural Research for Sustainable Food Systems with Special Reference to Sri Lanka. For detailed explanations of the recommendations, readers are referred to the information source (Marambe et al., 2020).

investigations are therefore highly needed to benchmark and identify strengths and weaknesses to identify opportunities and threats to the animal-source food sector. Since Sri Lankan agricultural and livestock production sector is closely interconnected and has been standing for a longer period, the focus is thus should be given to an approach that counts the blend of modern and traditional technologies for sustainable growth in the animal-source food sector. For an efficient recovery and balanced approach to establishing resilence in animal-source food systems, recommendations provided by a group of agricultural experts in Sri Lanka are highly merited as summarized in Figure 6, based on the detailed discussion available in the literature (Marambe et al., 2020).

## 5. Conclusions

Sri Lankan livestock and poultry industry and value chain are recovering from the impact of COVID-19 pandemic-related trade issues and the economic crisis in 2022, acknowledging its resilience. The speed and complete recovery of the value chain depend entirely on the adaptation of purposed measures in this article

as well as transdisciplinary collaboration, involving other experts in livestock and poultry, health, agriculture, food sector and policymakers. However, capacity building and empowering local small-scale farmers are essential to increase the resilience of the system. Upgrading the value chain will strengthen the Sri Lankan livestock and poultry farmers and increase the competitiveness of local production against imported commodities. For the sustainable and resilient transformation of the animal-source value chain in Sri Lanka with greater value addition, local and small-scale enterprises in the value chain should be focused on eliminating the redundancies and implementing missing components in the value chain. Hence policymakers and all stakeholders should consult multidimensions of this scenario in building resilience in animal-source food systems

## Acknowledgements

Figure 2 and 3 were created using Biorender.

## Authors' contributions

HP: Conceptualization; Writing – Original Draft, Review and Editing; Visualization. JKV: Writing – Review and Editing.

## Disclosure statement

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.

## About the author

***Hasitha Priyashantha*** is a notable researcher in the field of food science, currently affiliated with the Swedish University of Agricultural Sciences (SLU). His work primarily focuses on dairy science, with a special interest in how various farm factors influence the composition and quality of raw milk and cheese. He completed his PhD at SLU's Department of Molecular Sciences, where his thesis research was recognized with several prestigious awards. In 2021, his review article on the impact of farm factors on milk and cheese quality won the American Dairy Science Association's award for the best review article written by a doctoral student. He has also been honored for his presentations, receiving the 'Best Presenter' award at the International Dairy Federation's Cheese Science and Technology Symposium in 2021 for his work on using near-infrared hyperspectral imaging to model cheese ripening. With a strong commitment to advancing dairy science, his collaborates with various researchers and industry experts to promote innovations in the field. His contributions are helping to enhance the understanding and practices of dairy production, benefiting both academia and the industry.

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## Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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