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RESEARCH

# Economic Performance and Sustainability Challenges of Broiler Production in Egypt: A Case Study in Qalyub Governorate

Ibrahim Mohammad Abd Elaziz Alhfny[1], Elzaabalawy Mohamed Elshahat[1*], Samir Attia Aram[1], and Nashwa Samir Shoaib[1]

[1] Agricultural Economics Research Institute, Agricultural Research Center, Giza, Egypt

[*] Author who is responsible for correspondence; Email: elzabalawim@yahoo.com

## Abstract

This study investigates the economic performance and sustainability challenges of broiler production in Egypt, focusing on Qalyubia Governorate. It addresses the persistent national white meat deficit, suboptimal self-sufficiency, and significant market price volatility, largely driven by escalating input costs and consumer demand. Utilizing a mixed-methods approach with primary data from 20 purposively sampled farms in Banha and Toukh, the research reveals a national average poultry meat self-sufficiency rate of approximately 96.4% (2010-2022), indicating a narrow but chronic food gap. At the farm level, broiler production shows high profitability, with an average net return per 45-day cycle of EGP 185,420 and a return on invested capital (ROIC) of EGP 0.33, exceeding traditional bank investment returns. However, this profitability is precarious due to overwhelming reliance on costly inputs (feed, chicks, contributing ~86% of total costs) and significant marketing challenges, identified by 80-90% of farmers. The study highlights both economic resilience and acute vulnerabilities, advocating for interventions to stabilize markets, enhance resource efficiency, and support local feed supply chains for long-term sustainability.

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**Statement of Sustainability:** This study addresses the critical intersection of economic viability and environmental sustainability in Egypt's broiler industry, a key sector for achieving food security (SDG 2). It evaluates sustainability across key economic (e.g., profitability, cost structure, return on investment), environmental (e.g., resource use efficiency for water and energy, waste management practices like manure recycling), and social (e.g., employment generation, farmer perceptions, generational transfer) dimensions. By analyzing production costs, resource use, and farmer perspectives, our findings highlight pathways to enhance farm profitability while promoting a circular economy through better waste management (manure recycling) and encouraging resource efficiency (water and energy). This research provides actionable insights for policymakers and producers to foster a more resilient and sustainable poultry sector, contributing to responsible consumption and production patterns (SDG 12).

## 1. Introduction

The poultry industry represents a critical pillar of animal protein production in Egypt, substantially contributing to the nation's supply of white meat. As a relatively affordable and widely accepted alternative to red meat, it plays a significant role in the food security of the Egyptian population (Mottet and Tempio, 2017). Since the early 1980s, the sector has expanded considerably across all governorates, driven by the inherent advantages of broiler production, including a short fattening period, rapid capital turnover, minimal land requirements, and high feed conversion efficiency (Abu-Dieyeh, 2005; Attia et al., 2017). Consequently, the poultry industry is integral to national food security programs aimed at bridging the nutritional gap. However, this intensive production system faces growing scrutiny over its environmental footprint, including significant water and energy consumption, waste management challenges, and greenhouse gas emissions. Achieving sustainability requires balancing economic viability with environmental responsibility. A comparative analysis reveals that Egypt's per capita poultry consumption (approx. 10 kg/annum, FAO, 2019) is considerably lower than in countries like Kuwait (97.5 kg), Saudi Arabia (42 kg), and the United States (49 kg),

underscoring the imperative to examine the industry's current status (Zulfiqar and Thapa, 2017).

While previous studies have highlighted the national importance and general challenges of Egypt's poultry sector (Abdel-Aal and Sabry, 2021; Abdel-Wahab, 2022), there remains a gap in comprehensive, up-to-date analyses that simultaneously integrate macro-level trends, micro-level economic performance, farmer-perceived operational constraints, and nascent sustainability practices within a specific high-production region. Existing literature often provides a broad overview or focuses on singular aspects like efficiency, without sufficiently bridging the gap between national food security imperatives and the ground-level economic and environmental realities faced by producers.

The core problem addressed by this research is multifaceted, encompassing a discernible nutritional gap in white meat and a consistently low national self-sufficiency rate. This situation is exacerbated by significant price instability observed in recent years. Illustratively, broiler prices escalated from approximately EGP 29.7/kg in January 2023 to EGP 96/kg by early 2024, representing an increase of approximately 223%. Such volatility is attributed to a confluence of factors, including geopolitical events impacting global supply chains, which increase prices for essential inputs like feed, alongside heightened consumer demand. These issues are compounded by numerous operational challenges confronting poultry enterprises, ultimately constraining production.

Therefore, this study aims to fill this critical gap by providing a comprehensive and integrated analysis of the current state of the broiler industry in Egypt, utilizing a detailed case study in Qalyubia Governorate. Specifically, it seeks to: (1) analyze trends in national production and consumption to assess the food gap; (2) characterize the operational features and efficiency of farms in the study sample; (3) estimate production costs and financial returns at the farm level; (4) identify key constraints and farmer-proposed solutions; and (5) critically evaluate the sustainability implications of current production practices, thereby proposing targeted mitigation strategies and policy recommendations.

## 2. Methodology

This research employed a combination of descriptive and quantitative analytical methods. The descriptive approach involved defining theoretical concepts and outlining economic parameters relevant to broiler production, while the quantitative approach focused on analyzing relationships between economic variables using percentages, index numbers, and simple linear regression models.

Data were sourced from both secondary and primary channels. Secondary data were compiled from bulletins issued by the Ministry of Agriculture, the Central Agency for Public Mobilization and Statistics (CAPMAS), online databases, and records from the Animal Production Department in Qalyubia. In addition to economic parameters, data on farm inputs (water, energy, feed) and outputs (manure) were used to assess key sustainability aspects of the production practices. Primary data were collected through a structured questionnaire during a field survey conducted in November 2023. A purposive sample of 20 broiler production farms was selected, equally divided between the Banha and Toukh centers in Qalyubia Governorate. These centers were chosen due to their leading contribution to the governorate's total number of broiler farms, as detailed in **Table 1**. Banha center ranks first with 309 farms (33.4%), and Toukh center is second with 269 farms (29.1%). Ten farms were randomly selected from each center using lists obtained from the Qalyubia Directorate of Agriculture **Figure 1** (Directorate of Agriculture in Qalyubia, 2023). Data were gathered via personal interviews with farm owners or tenants during October and November 2023.

### 2.1. Justification for Sample Size and Generalizability

The selection of 20 farms, while representing a small proportion of the total farms in Qalyubia Governorate, was based on a purposive sampling strategy focusing on the two most significant production centers. This approach allows for an in-depth case study analysis of operational specifics, economic performance, and sustainability challenges within these key areas. While the findings provide rich, contextualized insights and highlight critical issues pertinent to the broader Egyptian broiler sector, the quantitative results should be interpreted with caution regarding their direct generalizability to all farms across the entire governorate or the nation. The study's strength lies in its detailed examination of the specific dynamics within a vital regional production hub, serving as a foundation for future, larger-scale investigations.

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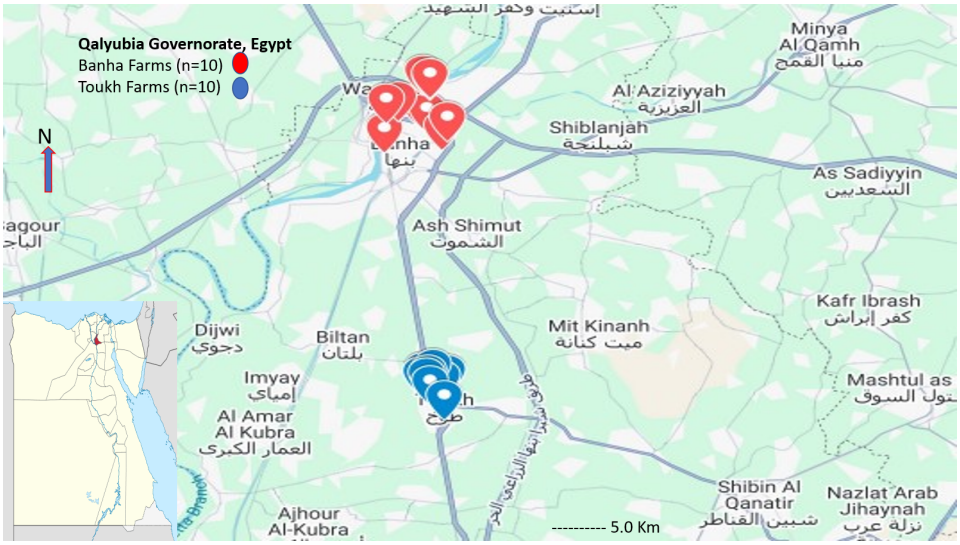


**Figure 1.** Map of the study area. The map shows Qalyubia Governorate, Egypt, highlighting the administrative centers of Banha and Toukh. The locations of the 20 sampled broiler farms are shown (10 in each center). Note: The points indicate the general areas of the sampled farms and are not the exact geographic coordinates, to maintain the confidentiality of the participants (Imagery ©2025, Map data ©2025 Google).

**Table 1.** Relative Importance of Broiler Chicken Farms in Qalyubia Governorate Centers (2022/2023).

| Center | Number of Farms | % of Total | Rank | Sampled Farms (No.) |
|---|---|---|---|---|
| Banha | 309 | 33.4 | 1 | 10 |
| Kafr Shukr | 171 | 18.48 | 3 | - |
| Toukh | 269 | 29.08 | 2 | 10 |
| Qalyuob | 65 | 7.02 | 5 | - |
| Al-Qanater Charity | 20 | 2.16 | 6 | - |
| Shibin Al-Qanater | 80 | 8.65 | 4 | - |
| Khanka | 11 | 1.19 | 7 | - |
| Total Governorate | 925 | 100 | - | 20 |

Source: Qalyubia Agriculture Directorate, Animal Production Department in 2022.

## 3. Results and Discussion

This study provides a macro-level analysis of the Egyptian white meat sector by examining national secondary data spanning the period from 2010 to 2022. This establishes the broader context concerning production, consumption, the national food gap, and self-sufficiency. Subsequently, the transitions to a micro-level investigation, presenting the detailed findings from the field study conducted in Qalyubia Governorate, which aims to uncover the grassroots factors influencing the national trends.

### 3.1. National Context: An Examination of Egypt's White Meat Sector (2010-2022)

#### 3.1.1. Evolution of White Meat Production and Consumption

- **Production Trends:** As presented in **Table 2**, the average annual white meat production in Egypt from 2010 to 2022 was approximately 1,486.92 thousand tons. Production fluctuated, with a minimum of 949 thousand tons in 2010 and a maximum of 2,358 thousand tons in 2021. The production index, using 2010 as a baseline, peaked at 248.47% in 2021. A general time trend analysis (**Table 4** and Eq. 1) indicates a statistically significant annual increase of 46.11 thousand tons, representing approximately 3.1% of the average production volume. The high coefficient of determination ($R^2$) of 0.86 confirms the strength of this trend.
- **Consumption Trends:** In parallel, domestic white meat consumption also showed a strong upward trajectory,

as detailed in **Table 2**. Consumption increased from 974 thousand tons in 2010 to a peak of 2,407 thousand tons in 2021, with an average of 1,531 thousand tons over the period. The consumption index surged to 247.12% in 2021. Time trend analysis (**Table 4** and Eq. 2) confirms this rapid growth, showing a statistically significant annual increase of approximately 110.84 thousand tons, or about 7.24% relative to the average consumption level. An $R^2$ of 0.89 indicates that 89% of consumption change is explained by the time trend.

The data clearly illustrate a critical dynamic: while domestic production has been growing steadily, the rate of consumption growth has been more than double that of production (7.24% vs. 3.10% annually). This widening gap points to a structural imbalance within Egypt's food security framework. The surge in consumption is likely driven by a combination of factors, including rapid population growth, increasing urbanization, and the sustained position of poultry as a more affordable protein source compared to red meats, consistent with global trends in developing economies (Mottet and Tempio, 2017). However, the comparatively slower growth in production signals deep-seated challenges within the domestic poultry industry. These include rising input costs, particularly for feed, and a heavy dependency on imported feed ingredients, which can significantly limit the sector's ability to scale up in response to escalating domestic demand (Burek et al., 2022). This imbalance underscores the critical need for strategic interventions to enhance domestic production capacity, a finding consistent with concerns raised by other studies on agricultural self-sufficiency in Egypt (Gantuz et al., 2019).

**Table 2.** Development of White Meat Productionand Consumption in Egypt (2010-2022).

| Year | Production (Thousands Tons) | Production Index (2010=100) | Relative Importance (%) | Consumption (Thousands Tons) | Consumption Index (2010=100) | Relative Importance (%) |
|---|---|---|---|---|---|---|
| 2010 | 949 | 100 | 4.90 | 974 | 100 | 4.89 |
| 2011 | 1000 | 105.3 | 5.17 | 1035 | 106.26 | 5.20 |
| 2012 | 1036 | 109.16 | 5.35 | 1072 | 110.06 | 5.38 |
| 2013 | 1187 | 125.07 | 6.14 | 1237 | 127.00 | 6.21 |
| 2014 | 1287 | 135.61 | 6.65 | 1322 | 135.73 | 6.64 |
| 2015 | 1293 | 136.25 | 6.69 | 1385 | 142.19 | 6.95 |
| 2016 | 1258 | 132.56 | 6.50 | 1345 | 138.09 | 6.75 |
| 2017 | 1303 | 137.30 | 6.74 | 1400 | 143.73 | 7.03 |
| 2018 | 1575 | 165.96 | 8.14 | 1624 | 166.73 | 8.15 |
| 2019 | 1900 | 200.21 | 9.82 | 1973 | 202.56 | 9.91 |
| 2020 | 2156 | 227.18 | 11.15 | 2078 | 213.53 | 10.24 |
| 2021 | 2358 | 248.47 | 12.19 | 2407 | 247.12 | 12.09 |
| 2022 | 2028 | 213.69 | 10.49 | 2051 | 210.57 | 15.30 |
| Total | 19330 | - | 100 | 19903 | - | 100 |
| Average | 1486.92 | 156.68 | - | 1531.00 | - | - |

Source: Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Food Balance Bulletin, various issues.

### 3.1.2. The National Food Gap and Self-Sufficiency in White Meat

- **Evolution of the Nutritional Gap:** The nutritional gap is defined as the difference between domestic production and consumption. As detailed in **Table 3**, Egypt consistently experienced a nutritional deficit in white meat for most years under review, indicating persistent market instability. A significant exception was observed in 2020, which recorded a surplus of approximately 78 thousand tons. This is widely interpreted as a temporary anomaly resulting from altered consumption behaviors and logistical disruptions during the COVID-19 pandemic, rather than a fundamental shift in productive capacity. The general time trend analysis for the food gap (**Table 4**, Eq. 3) indicates a slight, but statistically non-significant, annual increase in the deficit of 1.8 thousand tons. The lack of statistical significance, coupled with a low $R^2$ of 0.07, suggests that while the gap persists, its year-to-year size is highly volatile and not following a predictable linear trend.
- **Evolution of the Self-Sufficiency Rate (SSR)**: The SSR, calculated as (Domestic Production / Domestic Consumption) × 100, provides a clear metric of the nation's ability to meet its own demand. According to Table 3, the SSR for white meat averaged approximately 96.75% over the period. The lowest rate was recorded in 2017 at

93.07%, while the highest rate of 103.75% was achieved in 2020, coinciding with the pandemic-induced surplus. The time trend analysis (**Table 4**, Eq. 4) shows a marginal and statistically non-significant annual increase in the SSR of approximately 0.23%.

- **Discussion of Food Gap and SSR:** The analysis of the food gap and SSR reveals a critical stagnation in Egypt's journey toward poultry self-sufficiency. An average SSR of nearly 97% might appear robust, but the lack of statistically significant improvement over a 13-year period is a major concern for long-term food security. This indicates that despite efforts, the nation remains in a precarious position, chronically dependent on imports to fill a small but persistent gap (Zulfiqar and Thapa, 2017). This dependency exposes the Egyptian market to the volatilities of international trade, currency fluctuations, and global supply chain disruptions, exacerbating price instability for consumers and producers alike. The findings from this national-level analysis underscore the urgent importance of understanding the micro-level, on-the-ground challenges faced by producers, which will be the focus of the subsequent section, to develop more effective strategies for enhancing self-sufficiency and market stability.

**Table 3.** Development of the amount of the food gap and the percentage of self-sufficiency in white meat in Egypt during the period (2010-2022).

| Years | Food gap (thousands Tons) | Standard number | Relative Importance % | Self Sufficiency % | Standard number | Relative Importance % |
|---|---|---|---|---|---|---|
| 2010 | 25 | 100 | 3.43 | 97.43 | 100 | 7.74 |
| 2011 | 35 | 140 | 4.80 | 96.61 | 99.15 | 7.68 |
| 2012 | 36 | 144 | 4.94 | 96.64 | 99.18 | 7.68 |
| 2013 | 50 | 200 | 6.85 | 95.96 | 98.49 | 7.63 |
| 2014 | 35 | 140 | 4.80 | 97.53 | 100.10 | 7.75 |
| 2015 | 92 | 368 | 12.62 | 93.36 | 95.82 | 7.42 |
| 2016 | 87 | 348 | 11.93 | 93.35 | 95.81 | 7.42 |
| 2017 | 97 | 388 | 13.30 | 93.07 | 95.52 | 7.40 |
| 2018 | 49 | 196 | 6.72 | 96.98 | 99.54 | 7.71 |
| 2019 | 73 | 292 | 10.01 | 96.30 | 98.84 | 7.65 |
| 2020 | 78 | 312 | 10.70 | 103.75 | 106.48 | 8.24 |
| 2021 | 49 | 196 | 6.72 | 97.96 | 100.54 | 7.79 |
| 2022 | 23 | 92 | 3.15 | 98.87 | 101.48 | 7.86 |
| **Total** | 729 | - | 100 | 1257.81 | - | 100 |
| **Average** | 56.07 | - | - | 96.75 | - | - |

Source: Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Food Balance Bulletin, various issues.

**Table 4.** General Time Trend Equations for Key Indicators of the White Meat Sector in Egypt (2010-2022).

| No | Dependent Variable | General Trend Equation | $R^2$ | F-value | Annual Change (%) |
|---|---|---|---|---|---|
| 1 | White meat production | $\hat{Y} = 699.65 + 46.11X_t$ (t=8.39**) | 0.86 | 70.52** | +3.10 |
| 2 | White meat consumption | $\hat{Y} = 755.12 + 110.84X_t$ (t=9.45**) | 0.89 | 89.39** | +7.24 |
| 3 | Nutritional gap | $\hat{Y} = 43.46 + 1.80X_t$ (t=0.92) | 0.07 | 0.85 | +3.21 |
| 4 | Self-sufficiency rate | $\hat{Y} = 95.08 + 0.23X_t$ (t=1.17) | 0.11 | 1.37 | +0.23 |

Note: $\hat{Y}$ is the estimated dependent variable; Xt is the time variable (1-13). ** Significant at $p < 0.01$. Values in parentheses are t-statistics; Source: Calculated from Ministry of Agriculture, Economic Affairs Sector, Food Balance Bulletin.

## 3.2. Field Study Results: Farm-Level Dynamics in Qalyubia Governorate

### 3.2.1. Characteristics of Broiler Production Farms

The structural and financial characteristics of the farms, as detailed in **Table 5**, reveal a sector characterized by a mix of formal and informal operations, diverse financing strategies, and a blend of traditional and modern management approaches.

- **Farm Ownership and Legality:** The study sample was evenly split between owner-operated (50%) and rented farms (50%). A significant finding is the high prevalence of unlicensed operations, constituting 55% of the total sample. The proportion of unlicensed farms was notably higher in Banha (60%) compared to Toukh (50%). This informality poses a significant barrier to accessing formal credit, government support programs, and premium markets, potentially limiting the scalability and long-term sustainability of these enterprises.
- **Financing and Management:** Farm financing is diverse, with 40% relying on private capital, 20% on loans, and 40% utilizing a hybrid of both. This indicates that while personal investment is foundational, external credit plays a vital role in the operational continuity of the sector. Farm management is similarly varied, with a near-even split between owner-managed farms (45%) and those managed by third-party experts (35%), while 20% employ a dual management approach. This suggests a sector in transition, where traditional owner-led practices coexist with a growing reliance on specialized expertise.
- **Generational Aspect:** A noteworthy finding is that 55% of the farm operations are inherited, indicating a strong tradition and generational transfer of knowledge within the sector. Conversely, 45% of operations were initiated by individuals new to the industry, highlighting the sector's continued attractiveness for new investment despite its challenges.

**Table 5.** Characteristics of Sampled Broiler Farms in Qalyubia Governorate (2023).

| Statement | | First place in Benha | | Second place Toukh | | Total sample | |
|---|---|---|---|---|---|---|---|
| | | Number | Percent | Number | Percent | Number | Percent |
| Farm ownership | Owned by owner | 4 | 40 | 6 | 60 | 10 | 50 |
| | Rented | 6 | 60 | 4 | 40 | 10 | 50 |
| Farm legality | Total | 10 | 100 | 10 | 100 | 20 | 100 |
| | Licensed | 4 | 40 | 5 | 50 | 9 | 45 |
| | Not licensed | 6 | 60 | 5 | 50 | 11 | 55 |
| Number of farm floors | Total | 10 | 100 | 10 | | 20 | 100 |
| | One turn | 4 | 40 | 5 | 50 | 9 | 45 |
| | Two floors | 4 | 40 | 3 | 30 | 7 | 35 |
| | Three floors | 2 | 20 | 2 | 20 | 4 | 20 |
| Source of capital | Total | 10 | 100 | 10 | 100 | 20 | 100 |
| | private | 3 | 30 | 5 | 50 | 8 | 40 |
| | Loans | 2 | 20 | 2 | 20 | 4 | 20 |
| | Both together | 5 | 50 | 3 | 30 | 8 | 40 |
| Farm management | Total | 10 | 100 | 10 | 100 | 20 | 100 |
| | Farm owner | 4 | 40 | 5 | 50 | 9 | 45 |
| | off the farm | 4 | 40 | 3 | 30 | 7 | 35 |
| | Both methods | 2 | 20 | 2 | 20 | 4 | 20 |
| Exercise | Total | 10 | 100 | 10 | 100 | 20 | 100 |
| | inherited | 6 | 60 | 5 | 50 | 11 | 55 |
| | New | 4 | 40 | 5 | 5 | 9 | 45 |
| | Total | 10 | 100 | 10 | 100 | 20 | 100 |

Source: Collected from field study data in Qalyubia Governorate, 2024.

### 3.2.2. Operational and Management Practices

The daily operational and management practices employed by the farms, summarized in **Table 6**, offer critical insights into resource management, supply chain integration, and marketing strategies, which directly impact both profitability

and sustainability.

- **Input Sourcing (Chicks and Feed):** Producers source chicks from a mix of government companies (45%), private companies (35%), and direct imports (20%). This diversification may serve as a risk mitigation strategy against supply disruptions. A crucial finding relates to feed sourcing: 45% of farms prepare their feed on-site. This practice is significant, as it not only allows for better cost control but also presents an opportunity for utilizing local ingredients, potentially enhancing the operation's sustainability by reducing the carbon footprint associated with transporting pre-mixed feeds (Elnesr et al., 2020).
- **Resource Management (Labor, Water, and Energy):** The sector heavily relies on a temporary workforce, with 75% of labor hired on a cyclical basis, reflecting the fluctuating labor demands of the all-in, all-out production system. In terms of natural resources, there is a strong preference for groundwater (60% of farms) over municipal water (25%), primarily driven by cost considerations. Similarly, while the public electricity grid is the primary power source (45%), a significant portion of farms (35%) rely on private generators, indicating either an unreliable public supply or a strategy to mitigate power outages.
- **Veterinary Care and Litter Management:** Veterinary supervision is predominantly reactive rather than proactive. A combined 85% of farms engage veterinarians either on a per-cycle basis (40%) or only when a problem arises (45%), with only 15% retaining a fixed veterinarian. This approach may lead to higher long-term costs associated with disease outbreaks and reduced overall bird health. For litter (bedding), 55% of farms produce it themselves from agricultural by-products, a positive indicator of resourcefulness and a step towards a circular economy model.
- **Marketing and Sales Channels:** Marketing strategies are highly diversified. The largest share of sales is channeled through contracts with restaurants and large stores (35%), followed closely by sales to wholesalers (30%). Direct sales to retailers (15%), slaughter shops (10%), and consumers (10%) make up the remainder. This multi-channel approach helps producers access different market segments and potentially stabilize revenue streams.
- **Waste Valorization (Manure/Sabla):** A key sustainability-related finding is the universal practice of selling poultry manure (sabla). The primary buyers are owners of newly reclaimed land (55%), who use it to improve soil fertility. This practice of "waste valorization" is an excellent example of a circular economy in action, turning a potential pollutant into a valuable agricultural input and generating a secondary income stream for the farmers (Makkar, 2017).

### 3.2.3. Farmer Perceptions of Broiler Farming Viability

To understand the socio-economic drivers and challenges from the producers' perspective, the study surveyed their opinions on profitability, operational challenges, and future outlook. The results, presented in **Table 7**, paint a picture of a resilient but pressured sector.

- **Perceived Profitability and Performance:** Producers identified specific production cycles—notably January, March, and November—as the most profitable. This seasonality is likely linked to milder weather conditions, which can improve feed conversion ratios and reduce bird stress, alongside potential peaks in consumer demand. A significant division of opinion exists regarding current versus past performance; while 45% of respondents feel the business climate has improved post-COVID-19, a majority (55%) believe conditions were better in previous years, citing lower input costs and more stable market conditions as key factors.
- **Motivations and Deterrents:** The primary motivation for continuing in the broiler business is its role as a vital source of employment (55%), followed by its perceived profitability (25%) and potential as a good investment (20%). However, significant deterrents cause producers to consider exiting the market. These are evenly distributed among high production costs (25%), extreme price volatility (25%), high operational risks (25%), and persistent production and marketing problems (25%). This balance indicates that farmers are contending with a complex array of interconnected economic and operational pressures.
- **Future Outlook and Generational Transfer:** Despite the challenges, a slight majority of producers (55%) expressed a desire for the profession to be inherited by the next generation. Key reasons cited for this optimism include the availability of operational assets and accumulated market knowledge. Conversely, 45% do not wish for their children to inherit the business, primarily due to concerns over increasing risks (30%) and declining prof-

**Table 6.** Operational and Management Practices on Sampled Broiler Farms (2023).

| Practice Area | Category | Banha Center (n=10) No. | Toukh Center (n=10) % | Total Sample (n=20) No. |
|---|---|---|---|---|
| Chick Sourcing | Imports | 2 | 20 | 2 |
| | Government companies | 4 | 40 | 5 |
| | Private companies | 4 | 40 | 3 |
| Chick Purchasing | Company contracts | 5 | 50 | 5 |
| | Open market | 3 | 30 | 4 |
| | Mixed sources | 2 | 20 | 1 |
| Labor Source | Family labor | 2 | 20 | 2 |
| | Hired (per cycle) | 7 | 70 | 8 |
| | Permanent hired labor | 1 | 10 | 0 |
| Feed Source | On-farm prepared | 4 | 40 | 5 |
| | Purchased | 4 | 40 | 3 |
| | Mixed sources | 2 | 20 | 2 |
| Veterinary Care | Full-time veterinarian | 2 | 20 | 1 |
| | Per-cycle contract | 4 | 40 | 4 |
| | On-call (as needed) | 4 | 40 | 5 |
| Water Source | Municipal water | 3 | 30 | 2 |
| | Groundwater | 5 | 50 | 7 |
| | Mixed sources | 2 | 20 | 1 |
| Electricity Source | Public grid | 5 | 50 | 4 |
| | Private generator | 3 | 30 | 4 |
| | Mixed sources | 2 | 20 | 2 |
| Litter Source | Farm-produced | 5 | 50 | 6 |
| | Purchased | 4 | 40 | 4 |
| | Mixed sources | 1 | 10 | 0 |
| Sales Channel | Contracts (restaurants/stores) | 4 | 40 | 3 |
| | Wholesalers | 3 | 30 | 3 |
| | Retailers | 1 | 10 | 2 |
| | Slaughter shops | 1 | 10 | 1 |
| | Direct to consumers | 1 | 10 | 1 |
| Manure Sales | To new landowners | 5 | 50 | 6 |
| | To established landowners | 3 | 30 | 3 |
| | Mixed buyers | 2 | 20 | 1 |

Source: Field survey data (2023).

itability (30%), reflecting a deep-seated uncertainty about the long-term sustainability of the profession under current conditions.

### 3.2.4. Key Factors Affecting Broiler Production

To quantitatively identify the most critical inputs influencing broiler weight gain, a multiple linear regression model was developed. The final live weight of the bird was the dependent variable, regressed against key production inputs. The resulting model is presented below:

$$\hat{Y} = -1.55 + 0.75X_1 + 0.15X_2 + 0.04X_3 \quad (4.16^{**})\ (3.25^{*})\ (-1.61), \quad R^2 = 0.86,\ F = 35.56^{**} \tag{1}$$

Where: $\hat{Y}$ = Estimated final bird weight (kg), $X_1$ = Quantity of feed consumed (kg), $X_2$ = Hours of skilled labor, $X_3$ = Value of medications and vaccines (EGP), Significant at $p < 0.05$; ** Significant at $p < 0.01$

The analysis of the regression model yielded significant insights. The coefficient of determination ($R^2$) of 0.86 indi-

**Table 7.** Producer Perceptions of Broiler Farming Viability in Qalyubia Governorate (2023).

| Statement | Banha (No.) | Banha (%) | Toukh (No.) | Toukh (%) | Total (No.) | Total (%) |
|---|---|---|---|---|---|---|
| **Most profitable cycles** | | | | | | |
| January session | 4 | 40 | 3 | 30 | 7 | 35 |
| March session | 3 | 30 | 4 | 40 | 7 | 35 |
| November session | 3 | 30 | 3 | 30 | 6 | 30 |
| **Total** | 10 | 100 | 10 | 100 | 20 | 100 |
| **Current Performance** | | | | | | |
| Better now | 4 | 40 | 5 | 50 | 9 | 45 |
| In previous years | 6 | 60 | 5 | 50 | 11 | 55 |
| **Total** | 10 | 100 | 10 | 100 | 20 | 100 |
| **Motivation for Continuing Activity** | | | | | | |
| Good job opportunity | 5 | 50 | 6 | 60 | 11 | 55 |
| Profitable no matter the circumstances | 3 | 30 | 2 | 20 | 5 | 25 |
| Good opportunity for investment | 2 | 20 | 2 | 20 | 4 | 20 |
| **Total** | 10 | 100 | 10 | 100 | 20 | 100 |
| **Reasons for Considering Withdrawal** | | | | | | |
| High costs | 2 | 20 | 3 | 30 | 5 | 25 |
| Price fluctuation | 3 | 30 | 2 | 20 | 5 | 25 |
| High risk | 2 | 20 | 3 | 30 | 5 | 25 |
| Problems in production and marketing | 3 | 30 | 2 | 20 | 5 | 25 |
| **Total** | 10 | 100 | 10 | 100 | 20 | 100 |
| **Desire to Inherit Profession** | | | | | | |
| He wants to inherit | 6 | 60 | 5 | 50 | 11 | 55 |
| He does not want to inherit | 4 | 40 | 5 | 50 | 9 | 45 |
| **Total** | 10 | 100 | 10 | 100 | 20 | 100 |
| **Reasons for Wanting to Inherit** | | | | | | |
| A better job opportunity than others | 2 | 20 | 3 | 30 | 5 | 25 |
| Availability of necessary assets for operation | 2 | 20 | 2 | 20 | 4 | 20 |
| Good knowledge of the markets | 2 | 20 | 1 | 10 | 3 | 15 |
| Knowledge of chick purchasing sources | 2 | 20 | 2 | 20 | 4 | 20 |
| **Total** | 10 | 100 | 10 | 100 | 20 | 100 |

Source: Collected from field study data in Qalyubia Governorate, 2024.

cates that the model successfully explains 86% of the variation in broiler final weight, confirming its strong predictive power.

- **Feed Quantity ($X_1$):** This variable was found to be the most critical factor, with a highly significant positive coefficient (0.75, $p < 0.01$). This result empirically confirms that for every 1 kg increase in feed consumption, the bird's weight is expected to increase by 0.75 kg, holding other factors constant. This underscores the centrality of feed quality and management in achieving production targets.
- **Labor Hours ($X_2$):** Skilled labor also had a statistically significant positive impact on bird weight (0.15, $p < 0.05$). This suggests that proper management, care, and monitoring by experienced workers contribute directly to better production outcomes, likely through improved health, reduced stress, and optimized feeding practices.
- **Medications and Vaccinations ($X_3$):** Interestingly, the value of medications and vaccines had a small and statistically non-significant effect on final weight. This does not imply that veterinary inputs are unimportant; rather, it may suggest that their primary role is in preventing mortality and disease (a binary outcome) rather than directly promoting weight gain among surviving birds.

### 3.2.5. Economic Analysis: Costs and Returns of a Production Cycle

A detailed economic analysis was conducted for a typical 45-day production cycle on a farm with a capacity of 5,000 chicks, representing the most common operational scale in the sample. Production Costs: The total cost of production per cycle averaged EGP 568,300 across the sample, with notable variations between Banha (EGP 583,000) and Toukh (EGP 555,150). As detailed in **Table 8**, the cost structure is overwhelmingly dominated by two items:

- **Feed Cost:** Constituting an average of 51.5% of total costs, feed is unequivocally the largest expense for producers. The lower feed costs observed in Toukh were attributed by farmers to a higher prevalence of on-farm feed manufacturing, which allows for better cost control and potentially reduces reliance on external market fluctuations, aligning with strategies proposed for cost reduction in the poultry sector (Burek et al., 2022).
- **Chick Cost:** The initial cost of day-old chicks was the second-largest expense, accounting for 34.3% of the total.

Together, these two inputs represent approximately 86% of the total variable costs, making producers extremely vulnerable to price fluctuations in the feed and chick markets. This high dependency on a few volatile inputs is a recurrent theme in poultry economic studies across different regions (AL-Sharafat et al., 2013; Tuffour and Appiah, 2020). All other costs, including labor (3.8%), medications (3.3%), utilities (2.5%), and rent (1.2%), were comparatively minor but collectively contribute to the overall financial burden and operational risk.

- **Revenue, Profitability, and Return on Investment:** The revenue and profitability analysis, summarized in **Table 9**, demonstrates that broiler farming can be a lucrative business, provided that market conditions are favorable.
- **Revenue Streams:** The primary source of revenue is the sale of live chickens, accounting for over 99.1% of total income. Secondary revenue from the sale of manure (sabla) and used sacks, while small (0.4% and 0.5% respectively), represents an important practice of waste valorization and a contribution to the circular economy. This diversification of income, even if minor, adds to the resilience of the farm operations.
- **Net Return:** The average net return per 45-day cycle for a 5,000-bird farm was EGP 185,652. However, profitability varied significantly between the two centers, with farms in Toukh achieving a much higher net return (EGP 224,770) than those in Banha (EGP 146,750). This difference is likely attributable to the lower production costs (especially feed) and slightly better production performance (higher average bird weight) observed in Toukh, highlighting regional variations in operational efficiency and input management.
- **Return on Invested Capital (ROIC):** The average return on the invested pound was EGP 0.33. This means that for every Egyptian pound invested in a production cycle, the farmer gains EGP 0.33 in profit. This is a substantial return, especially given that it is achieved within a short 45-day period. The ROIC in Toukh (EGP 0.40) was notably higher than in Banha (EGP 0.25), reinforcing the finding of superior economic performance in that center. This ROIC significantly surpasses typical returns from conventional financial instruments like bank deposits, explaining the continued attractiveness of the sector for investment despite its inherent risks. The calculated return on invested capital of EGP 0.33 in this study aligns with findings from other economic analyses in the region, which reported similar profitability indicators in Sharkia Governorate (Abdel-Aal an Sabry, 2021). Furthermore, studies in Jordan and Ghana also highlight the potential for high returns in broiler farming, albeit with significant risk

**Table 8.** Cost Structure for a 5,000-Chick Broiler Production Cycle in Qalyubia Governorate (2023).

| Cost Item | Unit | Banha Center (n=10) | | Toukh Center (n=10) | Total Sample Average (n=20) |
|---|---|---|---|---|---|
| | | Value (EGP) | Perc. of Total | Value (EGP) | Value (EGP) |
| **A. Variable Costs** | | | | | |
| 1. Day-old Chicks | 5,000 chicks @ EGP/chick | 200,000 | 34.30 | 190,000 | 190,000 |
| 2. Feed | 15 tons @ EGP/ton | 300,000 | 51.50 | 285,000 | 285,000 |
| 3. Labor | Wages per cycle | 21,000 | 3.60 | 22,500 | 22,500 |
| 4. Veterinary and Health | | | | | |
| – Vaccines and Fortifiers | Per cycle | 10,000 | | 10,000 | 10,000 |
| – Medications | Per cycle | 5,000 | | 6,000 | 6,000 |
| – Disinfectants | Per cycle | 3,000 | | 3,000 | 3,000 |
| Subtotal | | 18,000 | 3.10 | 19,000 | 19,000 |
| 5. Litter / Bedding | Per cycle | 3,500 | 0.60 | 2,400 | 2,400 |
| 6. Utilities | | | | | |
| – Water | Per cycle | 5,000 | | 4,000 | 4,000 |
| – Electricity | Per cycle | 10,000 | | 9,000 | 9,000 |
| Subtotal | | 15,000 | 2.60 | 13,000 | 13,000 |
| 7. Heating (Fuel) | Per cycle | 6,000 | 1.00 | 6,000 | 6,000 |
| **Total Variable Costs** | | **563,500** | **96.70** | **540,900** | **540,900** |
| **B. Fixed Costs** | | | | | |
| 1. Veterinary Supervision | Per cycle | 9,000 | 1.50 | 8,000 | 8,000 |
| 2. Farm Rent | Per cycle | 7,000 | 1.20 | 6,500 | 6,500 |
| 3. Local Fees | Per cycle | 500 | 0.10 | 500 | 500 |
| **Total Fixed Costs** | | **16,500** | **2.80** | **15,000** | **15,000** |
| **C. Total Production Costs (A+B)** | Per cycle | **599,000** | **100.00** | **555,900** | **555,900** |

Source: Field survey data (2023). Values are in Egyptian Pounds (EGP). Some totals may not sum perfectly due to rounding in original data.

and vulnerability to market fluctuations (Al-Sharafat et al., 2020; Tuffour and Appiah, 2020). This comparison reinforces the notion that while broiler production can be highly profitable, its sustainability is often challenged by external market forces and internal inefficiencies, necessitating strategic management and policy support.

## 3.3. Sustainability Implications of Current Production Practices

Beyond the economic analysis, this study assessed the sustainability of current broiler production practices by examining key environmental indicators such as waste management, resource use efficiency (water and energy), and feed sourcing. The findings reveal a mixed landscape of promising circular practices and significant opportunities for improvement (Elnesr et al., 2020).

- **Waste Management and Circular Economy:** A highly positive finding is the widespread practice of manure (sabla) valorization. The study found that 100% of farms sell manure to landowners (**Table 6**), effectively recycling nutrients back into local agriculture and reducing the need for synthetic fertilizers. This represents a tangible step towards a circular economy by transforming a potential pollutant into a valuable agricultural input (Makkar and El-Masri, 2017). However, the full potential for sustainable waste management remains largely untapped. Advanced techniques such as composting to create high-value organic fertilizer or anaerobic digestion for biogas production (which could offset energy costs and reduce greenhouse gas emissions) are not yet prevalent in the region.
- **Resource Use Efficiency (Water and Energy):** The data reveal a heavy reliance on critical natural resources,

**Table 9.** Revenue, Profitability, and Economic Efficiency of a 5,000-Chick Broiler Production Cycle in Qalyubia Governorate (2023).

| Performance Indicator | Unit | Banha Center (n=10) | Toukh Center (n=10) | Total Sample Average (n=20) |
|---|---|---|---|---|
| A. Production Performance | | | | |
| Birds Sold (after mortality) | Number | 4,800 | 4,850 | 4,825 |
| Average Live Weight per Bird | kg | 2.00 | 2.10 | 2.05 |
| Total Weight Sold | kg | 9,600 | 10,185 | 9,893 |
| B. Revenue (Gross Income) | | | | |
| Revenue from Chicken Sales | | | | |
| Price per kg | EGP | 75.00 | 76.00 | 75.50 |
| Subtotal (Chicken Revenue) | EGP | 720,000 | 774,060 | 746,922 |
| Revenue from Manure (Sabla) | EGP | 3,000 | 2,860 | 2,930 |
| Revenue from Used Sacks | EGP | 3,750 | 3,750 | 3,750 |
| Total Gross Revenue | EGP | 726,750 | 780,670 | 753,602 |
| C. Profitability Analysis | | | | |
| Total Production Costs (from Table 8) | EGP | 599,500 | 555,900 | 577,450 |
| Net Return (Profit) per Cycle | EGP | 127,250 | 224,770 | 176,152 |
| D. Economic Efficiency Indicators | | | | |
| Net Return per Bird Sold | EGP | 26.51 | 46.34 | 36.51 |
| Return on Invested Capital (ROIC) | Ratio | 0.21 | 0.40 | 0.31 |

Source: Field survey data (2023). Values are in Egyptian Pounds (EGP). ROIC is calculated as (Net Return / Total Production Costs). Some totals may differ slightly from the original due to rounding and consistent calculation methods.

with 60% of farms using groundwater and 45% depending primarily on the public electricity grid (as shown in **Table 6**). In the context of Egypt's national challenges with water scarcity and energy supply (Gantuz et al., 2019), optimizing the use of these resources is crucial for the sector's long-term sustainability. The high cost of utilities, which was identified as a key problem by farmers (**Table 10**), provides a strong economic incentive for adopting more efficient technologies. These could include investments in solar-powered generators to reduce reliance on the grid and mitigate energy price volatility, or the adoption of water-saving technologies like nipple drinkers, which are proven to reduce water waste in poultry farms.

- **Feed Sourcing and Sustainability:** As established, feed constitutes the largest production cost (~51.5%). The sector's reliance on purchased feed, which often contains imported ingredients like soy and corn, exposes farmers to global price shocks and carries a significant environmental footprint related to international transport and land-use change in exporting countries (Burek et al., 2022). The finding that 45% of farms prepare feed on-site is therefore highly encouraging from a sustainability perspective. This practice, if supported by policies that encourage the use of locally sourced alternative ingredients, can reduce transportation emissions, decrease import dependency, and strengthen local agricultural economies, thereby enhancing the overall resilience and sustainability of the operation. These elements collectively form the basis of our assessment of environmental sustainability within the framework of responsible consumption and production (SDG 12).

## 3.4. Producer-Identified Challenges and Proposed Solutions

To complete the picture, the study gathered producers' own perspectives on the most pressing challenges they face and the solutions they deem most effective. This participatory approach provides valuable, practical insights for policymaking. The problems and solutions, ranked by frequency of mention, are summarized in **Table 10**.

#### 3.4.1. Major Challenges Facing Producers

The challenges cited by farmers are overwhelmingly economic in nature, reflecting the intense cost-price squeeze affecting the sector.

- **High and Volatile Input Prices:** The rising prices of chicks and feed were universally identified as the top two problems, each accounting for approximately 11-12% of problem mentions. This was followed closely by the rising costs of medicines and vaccinations. This confirms that the profitability of the farms is highly sensitive to the cost of these three key inputs (Burek et al., 2022).
- **Marketing and Price Instability:** Marketing problems and general price fluctuations for finished birds were also ranked as major issues (9-10% of mentions). This indicates that farmers feel squeezed from both ends: rising costs of inputs and unpredictable revenue from outputs, creating an unstable business environment.
- **Operational Costs and Climate Factors:** Other significant concerns included high operational costs for utilities (water and electricity), skilled labor, and heating. Additionally, the impact of climate instability (e.g., heatwaves affecting bird mortality and growth) was highlighted as a growing challenge, pointing to environmental vulnerabilities that impact economic performance.

#### 3.4.2. Farmer-Proposed Solutions

The solutions proposed by the farmers are pragmatic and targeted, focusing on mitigating risks and improving control over the production and marketing processes.

- **Improving Market Linkages:** The most frequently cited solution was the need for stronger contracts with restaurants and large stores. This reflects a desire to move away from volatile open markets towards more stable, predictable sales channels, a strategy supported by studies on improving market efficiency (Hassan and El-Masry, 2021).
- **Cost Control Measures:** To combat high input costs, producers strongly advocated for on-farm feed manufacturing and training farm workers to handle routine vaccinations to reduce reliance on external veterinarians. These measures aim to internalize costs and enhance operational self-sufficiency.
- **Investing in Infrastructure:** To manage high utility costs and climate risks, farmers proposed investing in private generators and water motors, and installing fans and air conditioning systems. These investments highlight the need for modernization to adapt to environmental challenges and reduce operational vulnerabilities.
- **Risk Mitigation:** In response to extreme price volatility, some farmers saw temporary farm closure as a necessary, albeit drastic, measure to avoid devastating losses during market downturns, indicating the severity of market instability.

### 3.5. Study Limitations

The authors acknowledge that while the findings provide valuable insights into the broiler production sector in Qalyubia, as discussed in the methodology section, the study's sample size of 20 farms limits the generalizability of the quantitative results to the entire governorate or to Egypt as a whole. The purposive sampling of the two leading centers, while justified for a case study approach, may not capture the full diversity of practices in other areas. Therefore, future research with a larger, more geographically diverse, and randomly selected sample is recommended to validate and expand upon these findings.

## 4. Conclusion

This study has provided an integrated analysis of the economic performance and sustainability challenges within Egypt's broiler production sector, utilizing a national-level overview and an in-depth case study of 20 farms in Qalyubia Governorate. Our findings underscore the sector's critical national importance in addressing a persistent food gap, yet reveal a complex interplay of high profitability and acute vulnerability. Nationally, the analysis confirms a structural deficit, with consumption growth consistently outstripping domestic production. This leads to a stagnant self-sufficiency rate of approximately 96.4% and an enduring reliance on imports, exposing the market to global volatilities. At the farm level, the economic analysis highlights the significant financial potential of broiler production,

**Table 10.** Key Problems and Proposed Solutions in Broiler Farming as Identified by Producers in Qalyubia Governorate (2023)

| Rank | Problems Identified by Producers | Banha Mentions (No.) | Toukh Mentions (No.) | Total Mentions (No.) | Combined Mention Frequency (Percent) |
|---|---|---|---|---|---|
| 1 | High Chick Prices | 10 | 10 | 20 | 11.4 |
| 1 | High Feed Prices | 10 | 10 | 20 | 11.4 |
| 3 | Rising Medicine/Vaccine Costs | 8 | 10 | 18 | 10.3 |
| 4 | Marketing Problems | 8 | 9 | 17 | 9.7 |
| 4 | Price Fluctuation (for chicken) | 9 | 8 | 17 | 9.7 |
| 6 | High Utility Costs (Water & Electricity) | 7 | 8 | 15 | 8.6 |
| 6 | High Skilled Labor Wages | 7 | 8 | 15 | 8.6 |
| 8 | Veterinarians' High Wages | 8 | 7 | 15 | 8.6 |
| 9 | Impact of Climate Instability | 7 | 6 | 13 | 7.4 |
| 10 | High Litter (Bedding) Costs | 6 | 7 | 13 | 7.4 |
| 11 | High Heating Costs | 5 | 7 | 12 | 6.9 |
| **Total Mentions** | | **85** | **90** | **175** | **100.0** |
| 1 | Contract with Restaurants/Stores | 10 | 10 | 20 | 11.5 |
| 2 | On-farm Feed Manufacturing | 9 | 8 | 17 | 9.8 |
| 2 | Train Workers for Vaccinations | 9 | 8 | 17 | 9.8 |
| 4 | Invest in Generator/Water Motor | 9 | 7 | 16 | 9.2 |
| 4 | Judicious Use of Medicines | 7 | 9 | 16 | 9.2 |
| 6 | Use Fans/Air Conditioners | 8 | 8 | 16 | 9.2 |
| 7 | Pre-contract for Chick Purchases | 8 | 9 | 17 | 9.8 |
| 8 | Involve Family Labor | 7 | 7 | 14 | 8.0 |
| 9 | Good Farm Insulation for Heating | 7 | 8 | 15 | 8.6 |
| 10 | Temporary Farm Closure (if needed) | 6 | 7 | 13 | 7.5 |
| 11 | Use Farm Waste for Litter | 7 | 6 | 13 | 7.5 |
| **Total Mentions** | | **87** | **87** | **174** | **100.0** |

Source: Collected from field study data in Qalyubia Governorate, 2024.

demonstrating an average net return of EGP 176,152 and a substantial return on invested capital of EGP 0.31 within a short 45-day cycle. This high potential for returns explains the sector's continued attractiveness and resilience despite its inherent risks. However, this profitability is precarious. The quantitative analysis unequivocally established that production efficiency is critically dependent on feed and skilled labor, while the cost structure is overwhelmingly dominated by feed and chick expenses, together accounting for approximately 86% of total costs. This heavy reliance on a few volatile inputs makes producers acutely susceptible to market price fluctuations, a concern strongly echoed by farmers who identified rising input prices and output price instability as their foremost challenges. Furthermore, while the study identified commendable existing sustainable practices, such as universal manure recycling, it also high-

lighted significant opportunities to enhance resource use efficiency (water and energy) and strengthen sustainability through localized feed sourcing and more advanced waste management techniques. In essence, the sector functions as a high-risk, high-reward system, where economic viability is continuously threatened by external market forces and internal operational inefficiencies, necessitating targeted interventions to foster long-term stability and sustainable growth.

## 5. Recommendations

Based on the empirical findings of this study, the following policy and practical recommendations are proposed to enhance the economic resilience and environmental sustainability of Egypt's broiler sector:

- **Strengthen Local and Sustainable Feed Supply Chains:** Given that feed is the dominant cost factor, policies should prioritize reducing dependency on imported ingredients. This can be achieved by promoting research and cultivation of local alternative feed crops and providing targeted incentives for farmers to adopt on-farm feed manufacturing using these local resources. This strategic shift would not only reduce production costs but also lower transportation-related carbon emissions and insulate farmers from global price shocks, thereby contributing to food sovereignty.
- **De-risk the Market through Improved Price Discovery and Contracts:** To counter the crippling effects of price volatility on both producers and consumers, there is an urgent need to establish transparent price discovery mechanisms. This could involve developing a formal poultry exchange, implementing government-regulated pricing formulas, or providing real-time market information to farmers. Concurrently, facilitating formal contract farming arrangements between producers and large buyers (e.g., restaurants, retailers) can guarantee stable prices and secure markets for farmers (Hassan and El-Masry, 2021), mitigating revenue uncertainty.
- **Enhance Access to Finance and Formalization:** The high prevalence of unlicensed farms limits their access to formal credit and support systems. Streamlining the licensing process and providing accessible, low-interest loans through institutions like the Agricultural Bank of Egypt are crucial. These loans should be targeted not only at reactivating idle farms but also at enabling existing farms to invest in modern, sustainable technologies, improving their long-term viability.
- **Promote Resource Use Efficiency and Circular Economy Practices:** To effectively address the identified sustainability challenges, government programs should offer comprehensive technical and financial support for the adoption of water-saving (e.g., nipple drinkers) and energy-efficient (e.g., solar power) technologies. Furthermore, pilot projects should be initiated to explore advanced waste valorization techniques such as composting for high-value organic fertilizer production and anaerobic digestion for biogas generation, transforming environmental responsibilities into new revenue streams and reducing ecological footprints.
- **Invest in Human Capital and Infrastructure:** The study highlighted the importance of skilled labor in achieving better production outcomes. Establishing vocational training centers for poultry farm workers would improve technical skills, enhance productivity, and promote better animal welfare practices. Concurrently, ensuring the availability and affordability of high-quality chicks from local hatcheries and robust veterinary services is fundamental to de-risking the production process and safeguarding public health for farmers.

## Authors' Contributions

Samir Attia Aram: Conceptualization, Supervision; Ibrahim Mohammad Abdel Aziz Alhfny: Methodology, Supervision; Elzaabalawy M. E.: Data Curation, Formal Analysis, Investigation, Writing – Original Draft; Nashwa Samir Showeb: Validation, Writing – Review & Editing.

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