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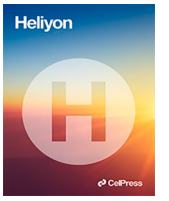

Research article

Comparative evaluation of management practices among large-scale broiler farms of Punjab, Pakistan

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ABSTRACT

Limited research is available on the management practices of commercial broiler chicken production in Pakistan. Notably, the rapid expansion of environmentally controlled broiler farms in Punjab in recent years remains underexplored, with scarce information on this growing enterprise. The current study compared the management practices at 100 commercial broiler farms in Punjab, Pakistan, among different regions. A questionnaire was filled by on farm veterinarians (n = 100; one veterinarian from each farm) regarding the general information, infrastructure, biosecurity practices, visitor history, and production analysis of the surveyed poultry farms. The results of the survey revealed that the majority of the farms had environmentally controlled housing systems with rearing capacity of 75,000 broiler chickens or more; mostly having Cobb 500 and Ross 308 broiler strains. The infrastructure of >60 % of farms was found to be good with best biosecurity practices. The most commonly observed average downtime was 2–3 weeks plus washing with chlorinated water and detergent after dry cleaning at farms. The water quality regarding TDS and pH level was found normal at the majority of the farms. Traffic status was observed with random results at different farms, while in the Multan region, biosecurity practices were strict with no visits. The dead birds' removal time of 3–5 days was more common. Dead bird disposal through the pit method was more prevalent in most of the broiler farms across the Punjab. Better FCR, adjusted FCR, and market age were observed in broilers in the Multan area while those in the areas of Sheikhupura and Kasur showed poor performance due to improper management practices. It was concluded that effective management practices on broiler farms in Punjab, Pakistan, contribute to improved performance and bird health. Future studies are needed to explore this area further and develop strategies to address challenges faced by poultry farmers.

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1. Introduction

Pakistan is ranked 11th position in terms of production among global poultry producers. At present, 1.55 billion of broiler chickens are produced on per annum basis. Moreover, the estimated annual poultry meat production is about 1,977000 tons [1]. In recent years, Pakistan's poultry sector has seen a major rise of environmentally controlled houses (ECH). Better feed efficiency, growth performance, better carcass traits and disease control in the flock are all guaranteed by environmentally controlled houses [2]. Since the year 2000, the industry has attracted significant investments from new stakeholders, leading to a transition in poultry farming practices from open-sided houses to modern environmentally controlled facilities [3]. The cost of production is also lower in environmentally controlled houses than in semi-controlled or open houses. An increment of 70 % in animal derived food is expected in future; within the time frame of 2005–2050, an increase of 121 % in poultry meat and 65 % in egg demand is anticipated [4]. In order to cope up with the rising demands of poultry products, the industry is relying on massive farming of meat and egg type chicken [5]. In 2018, global meat production totaled 342 million tons, with poultry meat accounting for approximately 119.7 million tons [6]. Poultry meat possesses an excellent nutritional profile by containing modest level of energy, highly digestible proteins, unsaturated lipids, vitamins and mineral content [7].

The future developments in the poultry industry are influenced by disease outbreaks, consumer confidence, product safety and quality [8]. Poultry production systems usually involve diversity with varying degree of production scales, bird type, level of biosecurity measures, production inputs and outputs. It is a general perception that housing and management practices of a farm affect the health and performance of broiler flocks [9–11]. Adoption of efficient and animal friendly management measures can ensure animal health [12]. An efficient ventilation system could be essential to mitigate the heat stress which is one of the major culprits to affect the productivity and immune status of an animal [13]. Methods of ventilation and air flow rates strongly influence the house indoor ammonia levels [14]. The ammonia levels of 50–75 ppm are known to hamper the productive performance of modern broilers; moreover, the continuous exposure may lead to inflammation of upper respiratory tract making it more susceptible to bacterial and viral infections [15,16].

Stocking density can be a source of stress in intensive poultry production system which is directly linked with performance, health, and welfare of poultry. The possible reason behind these outcomes could be increased competition for feed and water, behavioral changes and poor air and floor quality [17]. Furthermore, mild heat stress can occur due to rising environmental temperatures, which can hinder the body's heat dissipation mechanisms [18]. Environmental complexities can also induce fear and anxiety which render the animal incapable to cope up with the surroundings [19]. Environmental factors e.g., handling, noise and transportation have been associated with poor FCR [20].

The risk of disease transmission is increasing many folds in conventional poultry farming practices because of high stocking densities, low genetic variation, poor ventilation, and immunosuppression which represent a challenge for birds' health and welfare status [21]. Keeping in view these possible challenges, biosecurity is considered as a reliable tool to mitigate the disease outbreak risks within and between different farms [22]. From a global perspective, biosecurity risks in animal production sector have become a center of attention [22]. Zoonotic diseases often arise due to inadequate monitoring and ineffective implementation of biosecurity standards in animal production systems [23]. Apart from mitigating the disease outbreak risks, biosecurity also lowers down the need of antimicrobial administration which ultimately is an initial step to decrease the emerging incidence of antimicrobial resistance (AMR) [24]. Poor biosecurity practices facilitate the spread of diseases in poultry, increasing the reliance on antimicrobials and accelerating the development of AMR through selective pressure and environmental contamination. Strengthening biosecurity measures, such as sanitation, controlled access, and waste management, prevents disease outbreaks, reducing the need for antimicrobial usage. This approach not only curbs AMR but also promotes healthier flocks and sustainable poultry production.

Punjab, Pakistan, is characterized by perennial monsoons, extreme seasonal temperatures, and high population density, which challenge poultry farming with increased disease risks, biosecurity issues, and the need for climate-controlled housing. Additionally, its role as an agricultural hub and the region's cultural reliance on poultry for protein make it a significant area for studying sustainable production practices. The Punjab province was selected as the area under study because 70 percent of poultry farms in Pakistan are in this region [25]. Punjab, therefore, is the main poultry farming province in Pakistan. Holistically, there is a strong association between farm practices and possible production, health, and welfare outcomes in a poultry production system. To our knowledge, limited efforts have been placed to assess differences in routinely adopted farm practices and their possible consequences in different farms of Punjab. Research on commercial broiler management in Pakistan is limited, particularly regarding the rapidly growing environmentally controlled farms in Punjab. From the above discussion, present study was planned to compare the different farm management practices used in Punjab region and their influence on production performance and health status of broiler flocks.

2. Materials and methods

Firstly, about 120 commercial broiler farms in Punjab region were selected randomly for survey and then contacted the participants (1 veterinarian from each farm) for their consent; only 100 participants agreed, informed consent was obtained from all participants. Questionnaire containing the questions regarding the required information was developed and administered.

2.1. Farm surveys

A survey was conducted on-farm at commercial broiler farms mainly located in the Punjab region of Pakistan. A total of 100 commercial broiler houses located at Multan, Okara, Sahiwal, Depalpur, Sargodha, Burewala, Vehari, Sheikhupura, Manga mandi, Kot

Radha Keshen, Changa Manga, Kasur, Narowal, and Sukheki, were visited personally (Fig. 1). The large-scale farms with a population of ~30,000 birds' capacity were considered for survey.

A questionnaire was devised, incorporating inquiries about regularly employed farm practices, adapted from the researches [26, 27]. Questionnaire was divided into different sections having short closed, semi-closed and open questions (for detail information related to questionnaire provided in the supplementary material).

1. General information: Type of farm (Environmentally controlled or semi-controlled houses); Farm capacity for broilers (15000–30000, 31000–45000, 46000–60000, 61000–75000 or 75000+); Broiler strains reared (Ross 308, Cobb 500, Hubbard Classic, Arbor Acres).
2. Farm Infrastructure: Presence of foot dips (Yes or no); Sanitary transition zone/washing area (Yes or no); Presence of fence around farm (Yes or no); Housing secure against wild birds/animals (Yes or no); Presence of rat trappers (Yes or no).
3. Hygiene: Average down time (period of time between successive flocks when no chickens are present on the premises) (7–10 d, 11–14 d, 15–18 d, 19–22 d or 23–26 d); Cleaning and disinfection protocol details (Cleaning, formalin, Virkon spray; Dry cleaning and washing with chlorinated water and liquid detergent; Formalin solution and soap liquid spray; Liquid soup and caustic soda; Only formalin spray; Virkon spray, intramulti des GA); Flock arrival (All-in all-out or multiage); Access of wild birds to fresh litter or manure (Yes or no); Access of rodents to feed storage (Yes or no); Type of drinking and cleaning water i.e., TDS (300–500, 501–700, 701–900, 901–1100, 1101–1300 or 1301–1500); Type of drinking and cleaning water i.e., pH (6, 7, 8, 9, 10 or 11); Dead bird disposal (Pit or Composting); Frequency of visitors to the farm (Frequent, occasionally or not allowed).
4. Contacts/Movements to poultry premise: Veterinarian (Frequent, occasionally or not allowed); Manure or dead bird removal (After 3 days; after 5 days; after 7 days or after 15 days); Feed supplier (Before every flock or monthly basis); Litter supplier (Before every flock or monthly basis); Poultry supply and discharge (At early morning or at night); Sale of birds (Local vendor, employees or both).
5. Production analysis: Market age; Body weight at market; Mortality rate; Feed conversion ratio (FCR); and adjusted feed conversion ratio.

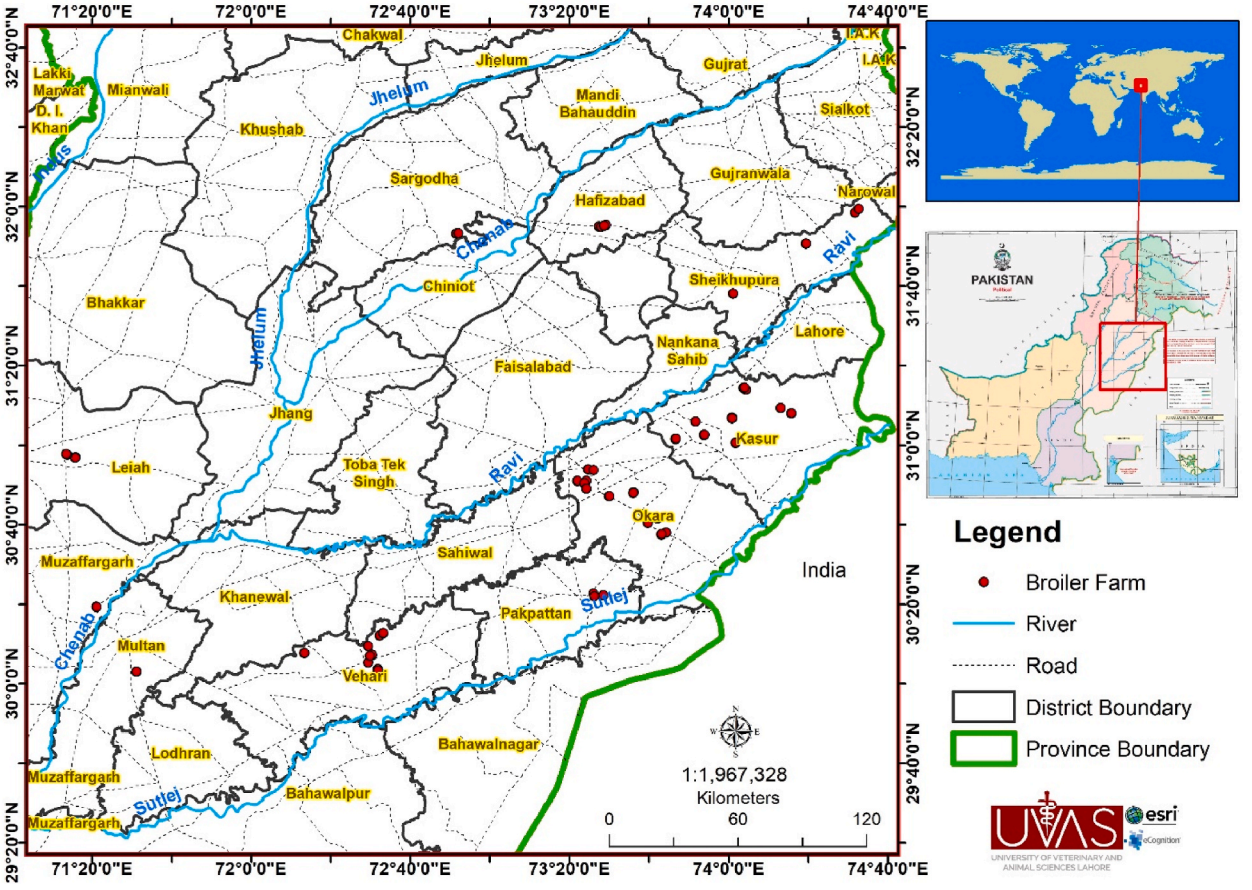

Fig. 1. Map of broiler farm locations.

2.2. Statistical analysis

For logical interpretation of data from respondents through a structured questionnaire; data were compiled, tabulated, and subjected to appropriate statistical analysis. For qualitative data frequency distribution and the percentage were computed. The association between variables was computed through the chi-square test. For quantitative data, one-way ANOVA was applied using PROC GLM (SAS software: version 9.1) assuming different cities of Punjab as main effects. Significant treatment means were compared using DMR test.

3. Results

3.1. General information

In Punjab, Pakistan, the majority of broiler farms (74 %) operate as environmentally controlled facilities, while the rest are semi-controlled houses or sheds. Farm capacities vary by area, influenced by shed dimensions and the number of sheds. Most environmentally controlled houses accommodate 30,000 or more birds, whereas the capacities of semi-controlled houses depend on company guidelines, location, and shed dimensions. Across Punjab, 41 % of farms had a capacity of 75,000+ birds, while the remaining farms were categorized as 46,000–60,000 (22 %), 61,000–75,000 (19 %), 15,000–30,000 (12 %), and 31,000–45,000 (6 %). The broiler strains commonly reared included Cobb 500 (31 %), Ross 308 (26 %), Arbor Acre (18 %), and Hubbard Classic (11 %). Additionally, 14 % of farms raised broilers based on strain availability (Table 1).

3.2. Farm Infrastructure

At broiler farms in Punjab, foot dips were present at 78 % of farms, washing areas at 69 %, fencing around farms at 66 %, secured housing to protect against wild birds and animals at 61 %, and rat traps at 54 %. A well-developed housing infrastructure was observed in the majority of farms (74 %). Overall, no significant association ($p > 0.05$) was found between farm infrastructure and the locations of broiler houses (Table 2).

3.3. Hygiene

In broiler farms, the average downtime between production cycles was most commonly 11–14 days (36 %), followed by 19–22 days (35 %), 15–18 days (20 %), and either 7–10 days or more than 22 days (9 %). The biosecurity protocols varied, with 45 % of farms practicing dry cleaning followed by washing with chlorinated water and detergent. In 34 % of farms, formalin solution and liquid soap spray were used for cleaning. Additionally, 8–10 % of farms employed Virkon (potassium peroxymonosulfate) spray along with intra multi des GA and a combination of liquid soap and caustic soda (Table 3).

This study showed that the 72 % of the farms in Punjab have birds of the same age across one or more sheds, while 28 % of the farms have multi-age flocks across different sheds. At 37 % of broiler farms, wild birds had no access to fresh litter or manure, and at 50 % of farms, rodents were effectively kept away from feed storage. The majority of farms in Punjab (80 %) used the pit method for bird disposal, while composting was practiced by only 20 %. Visitor frequency varied across farms, with frequent visits reported at 55 % of farms, occasional visits at 31 %, and restricted access at 14 % of farms where strict biosecurity measures were enforced (Table 4).

The Total Dissolved Solids (TDS) levels (mg/L) in drinking and cleaning water were observed across several ranges: 701–900 (45 %), 501–700 (26 %), 300–500 (13 %), 901–1100 (13 %), 1301–1500 (2 %), and 1100–1300 (1 %). Additionally, the recorded pH values included 8 (33 %), 7 (29 %), 6 (17 %), 9 (15 %), 10 (4 %), and 11 (2 %) (Table 5).

Table 1
General information of broiler farming located at Punjab, Pakistan.

Sr. No.	Questions		Frequency	Percent
1	Type of farm	Environmentally controlled	74	74.0
		Semi controlled	26	26.0
		Pooled	100	100.0
2	Capacity	15000–30000	12	12.0
		31000–45000	6	6.0
		46000–60000	22	22.0
		61000–75000	19	19.0
		75000+	41	41.0
		Pooled	100	100.0
3	Broiler strains reared	Anyone	14	14.0
		Arbor Acres	18	18.0
		Cobb 500	31	31.0
		Hubbard Classic	11	11.0
		Ross 308	26	26.0
		Pooled	100	100.0

Table 2
Broiler farm infrastructure located at different areas of Punjab, Pakistan.

Area	Presence of foot dips		Sanitary transition zone (Washing area)		Presence of fence (Around farm)		Housing secure against wild bird/animals		Presence of rat trappers	
	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)
Multan	25.0	75.0	25.0	75.0	50.0	50.0	50.0	50.0	37.5	62.5
Okara	20.0	80.0	50.0	50.0	20.0	80.0	50.0	50.0	60.0	40.0
Burewala	42.9	57.1	57.1	42.9	28.6	71.4	71.4	28.6	57.1	42.9
Vehari	28.6	71.4	28.6	71.4	28.6	71.4	–	100.0	71.4	28.6
Sahiwal	40.0	60.0	20.0	80.0	30.0	70.0	10.0	90.0	60.0	40.0
Sargodha	–	100.0	–	100.0	14.3	85.7	28.6	71.4	28.6	71.4
Sukheki	40.0	60.0	–	100.0	20.0	80.0	20.0	80.0	40.0	60.0
Narowal	50.0	50.0	50.0	50.0	–	100.0	50.0	50.0	50.0	50.0
Depalpur	25.0	75.0	50.0	50.0	37.5	62.5	37.5	62.5	25.0	75.0
Manga Mandi	–	100.0	40.0	60.0	40.0	60.0	40.0	60.0	40.0	60.0
Changa Manga	–	100.0	20.0	80.0	80.0	20.0	20.0	80.0	20.0	80.0
Kot Radha Keshen	25.0	75.0	25.0	75.0	50.0	50.0	62.5	37.5	62.5	37.5
Kasur	11.1	88.9	33.3	66.7	33.3	66.7	33.3	66.7	44.4	55.6
Sheikhupura	–	100.0	28.6	71.4	42.9	57.1	71.4	28.6	28.6	71.4
χ^2	14.15		12.71		11.75		19.14		9.53	
p-value	0.363		0.470		0.548		0.119		0.732	

Table 3
Average down time and detail of cleaning and disinfection protocol in different broiler farms located at Punjab, Pakistan.

Area	Average down time (%)					Cleaning and disinfection protocol (%)					
	7–10 d	11–14 d	15–18 d	19–22 d	23–26 d	Cleaning somaline Virkon spray	Dry cleaning and washing with Cl_2 water + liquid detergent	Formalin solution and soap liquid spray	Liquid soap and caustic soda	Only formalin spray	Virkon spray, intramultides GA
Multan	–	12.5	62.5	25.0	–	–	100.0	–	–	–	–
Okara	10.0	–	20.0	70.0	–	–	100.0	–	–	–	–
Burewala	–	14.3	71.4	14.3	–	28.6	42.9	14.3	14.3	–	–
Vehari	–	42.9	28.6	28.6	–	42.9	28.6	14.3	–	14.3	–
Sahiwal	–	60.0	–	40.0	–	40.0	30.0	30.0	–	–	–
Sargodha	–	71.4	–	28.6	–	14.3	14.3	57.1	–	–	14.3
Sukheki	–	40.0	20.0	40.0	–	20.0	60.0	20.0	–	–	–
Narowal	–	25.0	50.0	25.0	–	–	25.0	75.0	–	–	–
Depalpur	12.5	25.0	25.0	37.5	–	–	37.5	37.5	–	–	25.0
Manga mandi	–	40.0	–	40.0	20.0	–	40.0	60.0	–	–	–
Changa Manga	20.0	60.0	–	20.0	–	–	40.0	40.0	–	–	20.0
Kot Radha Kishen	12.5	37.5	–	25.0	25.0	–	25.0	62.5	–	–	12.5
Kasur	11.1	44.4	–	33.3	11.1	–	22.2	55.6	–	–	22.2
Sheikhupura	–	42.9	14.3	42.9	–	–	42.9	42.9	–	–	14.3
χ^2	69.16					94.082					
p-value[a]	0.056					0.011					

[a] Significant at $p \leq 0.05$.

3.4. Contacts/movement application to poultry premise

In broiler farms across Punjab, veterinarians visit frequently (66 %), occasionally (29 %), or, in some cases, are not permitted to visit (5 %) due to strict biosecurity measures. It was noted that most broiler farmers remove mortalities daily and dispose of them in a designated pit. The waste from these pits is cleared at varying intervals: 40 % of farmers do so after 3 days, 39 % after 5 days, and 16 % after 7 days or more (Table 6).

Poultry supply from broiler farms typically occurred twice daily, with 51 % of the supply taking place in the early morning and 49 % at night. Based on company guidelines, flock conditions, and market dynamics, farmers in Punjab, Pakistan, sold their live birds to employees (19 %), local vendors (18 %), or both (63 %), as shown in Table 7.

3.5. Production analysis

The current findings indicate that broiler farms in the Sheikhupura and Kasur regions had the longest market age (44 days),

Table 4
Hygiene related status in different broiler farms located at Punjab, Pakistan.

Area	Flock arrival (%)		Access of wild birds to fresh litter or manure (%)		Access of rodents to feed storage (%)		Dead bird disposal (%)		Frequency of visitors to the farm (%)		
	All-in all-out	Multiage	No	Yes	No	Yes	Composting	Pit	Frequent	Not Allowed	Occasionally
Multan	62.5	37.5	37.5	62.5	50.0	50.0	25.0	75.0	62.5	25.0	12.5
Okara	80.0	20.0	40.0	60.0	60.0	40.0	20.0	80.0	40.0	40.0	20.0
Burewala	71.4	28.6	42.9	57.1	71.4	28.6	28.6	71.4	57.1	–	42.9
Vehari	85.7	14.3	42.9	57.1	42.9	57.1	28.6	71.4	–	57.1	42.9
Sahiwal	80.0	20.0	40.0	60.0	60.0	40.0	10.0	90.0	10.0	40.0	50.0
Sargodha	100.0	–	85.7	14.3	85.7	14.3	–	100.0	14.3	–	85.7
Sukheki	80.0	20.0	40.0	60.0	40.0	60.0	20.0	80.0	60.0	–	40.0
Narowal	50.0	50.0	75.0	25.0	50.0	50.0	50.0	50.0	75.0	–	25.0
Depalpur	62.5	37.5	25.0	75.0	25.0	75.0	37.5	62.5	75.0	–	25.0
Manga mandi	60.0	40.0	20.0	80.0	40.0	60.0	–	100.0	80.0	–	20.0
Changa Manga	60.0	40.0	40.0	60.0	40.0	60.0	20.0	80.0	80.0	–	20.0
Kot Radha Kishen	75.0	25.0	25.0	75.0	50.0	50.0	12.5	87.5	62.5	–	37.5
Kasur	55.6	44.4	11.1	88.9	44.4	55.6	22.2	77.8	100.0	–	–
Sheikhupura	71.4	28.6	14.3	85.7	28.6	71.4	14.3	85.7	85.7	–	14.3
χ^2	7.805		15.672		9.797		8.626		59.544		
p-value[a]	0.856		0.267		0.710		0.801		0.0001		

[a] Significant at $p \leq 0.05$.

Table 5
Type of drinking and cleaning water in different broiler farms located at Punjab, Pakistan.

Area	TDS (mg/L)						pH					
	300-500 (%)	501-700 (%)	701-900 (%)	901-1100 (%)	1101-1300 (%)	1301-1500 (%)	6 (%)	7 (%)	8 (%)	9 (%)	10 (%)	11 (%)
Multan	–	25.0	62.5	12.5	–	–	25.0	50.0	12.5	12.5	–	–
Okara	20.0	40.0	20.0	20.0	–	–	20.0	30.0	40.0	10.0	–	–
Burewala	14.3	42.9	28.6	14.3	–	–	–	57.1	42.9	–	–	–
Vehari	71.4	–	14.3	–	–	14.3	42.9	42.9	14.3	–	–	–
Sahiwal	20.0	20.0	40.0	10.0	–	10.0	20.0	30.0	30.0	20.0	–	–
Sargodha	28.6	57.1	14.3	–	–	–	28.6	14.3	57.1	–	–	–
Sukheki	20.0	40.0	40.0	–	–	–	60.0	20.0	20.0	–	–	–
Narowal	–	25.0	50.0	25.0	–	–	25.0	25.0	–	50.0	–	–
Depalpur	–	25.0	50.0	25.0	–	–	–	25.0	25.0	25.0	12.5	12.5
Manga mandi	–	40.0	40.0	20.0	–	–	20.0	20.0	40.0	20.0	–	–
Changa Manga	–	20.0	80.0	–	–	–	–	20.0	60.0	–	20.0	–
Kot Radha Kishen	–	12.5	37.5	37.5	12.5	–	–	12.5	25.0	37.5	12.5	12.5
Kasur	–	22.2	66.7	11.1	–	–	–	33.3	55.6	11.1	–	–
Sheikhupura	–	–	100.0	–	–	–	14.3	14.3	28.6	28.6	14.3	–
χ^2	80.946						63.331					
p-value	0.088						0.535					

whereas the shortest market age (37 days) was recorded in Multan ($p < 0.0001$). Among the regions studied, Multan district in Punjab, Pakistan, demonstrated the most favourable FCR and adjusted FCR values ($p < 0.0001$). There were no significant differences ($p > 0.05$) in broiler body weight or mortality rates across the various regions of Punjab, Pakistan (Table 8).

4. Discussion

This study exhibited the knowledge of large-scale broiler chickens in Punjab, Pakistan by documenting managemental practices based on interviews conducted on-farm, and including general information, farm infrastructure, hygiene, and production analysis. To evaluate the broiler performance, housing systems, different production scales, bird species, measures of biosecurity, production inputs, and outputs are characterized. The disease introduction and spread probability in poultry premises are determined by stocking density, strains, contacts between flocks, and sanitary measures coupled with good biosecurity practices. The sample of the farm surveyed is likely representative of the commercial broiler farms across Punjab, given that Punjab is the leading state in both the number of farms and volume in Pakistan [2].

The study provides valuable insights into broiler farm management practices in Punjab, its findings may not be fully generalizable to other provinces of Pakistan. The reliance on a data sourced from veterinarians' reports may introduce bias and restrict the diversity of captured practices.

Table 6
Contact and movement status in different broiler farms located at Punjab, Pakistan.

Area	Veterinarian (%)			Manure or dead bird removal from pit (%)				Feed supplier (%)	
	Frequent	Not Allowed	Occasionally	After 3 days	After 5 days	After 7 days	After 15 days	Before every flock	Monthly basis
Multan	62.5	37.5	–	37.5	37.5	12.5	12.5	50.0	50.0
Okara	80.0	–	20.0	90.0	10.0	–	–	90.0	10.0
Burewala	57.1	–	42.9	42.9	57.1	–	–	57.1	42.9
Vehari	57.1	–	42.9	85.7	14.3	–	–	71.4	28.6
Sahiwal	70.0	–	30.0	50.0	20.0	30.0	–	60.0	40.0
Sargodha	42.9	–	57.1	–	100.0	–	–	57.1	42.9
Sukheki	20.0	40.0	40.0	–	60.0	40.0	–	100.0	–
Narowal	50.0	–	50.0	50.0	25.0	25.0	–	75.0	25.0
Depalpur	87.5	–	12.5	25.0	37.5	37.5	–	75.0	25.0
Manga mandi	80.0	–	20.0	20.0	40.0	40.0	–	60.0	40.0
Changa Manga	80.0	–	20.0	20.0	40.0	40.0	–	40.0	60.0
Kot Radha Kishen	62.5	–	37.5	12.5	37.5	50.0	–	25.0	75.0
Kasur	77.8	–	22.2	44.4	44.4	11.1	–	77.8	22.2
Sheikhupura	71.4	–	28.6	42.9	42.9	14.3	–	57.1	42.9
χ^2	45.052			57.201				15.030	
p-value[a]	0.012			0.030				0.305	

[a] Significant at $p \leq 0.05$.

Table 7
Litter supplier, poultry supply and sale of birds in broiler farms located at Punjab, Pakistan.

Area	Litter supplier (%)		Poultry supply (%)		Sale of birds (%)		
	Before every flock	Monthly basis	At early morning	At night	Employees	Local vendor	Both
Multan	75.0	25.0	50.0	50.0	37.5	12.5	50.0
Okara	100.0	–	40.0	60.0	10.0	30.0	60.0
Burewala	85.7	14.3	42.9	57.1	28.6	42.9	28.6
Vehari	85.7	14.3	85.7	14.3	28.6	28.6	42.9
Sahiwal	70.0	30.0	30.0	70.0	20.0	20.0	60.0
Sargodha	42.9	57.1	–	100.0	14.3	–	85.7
Sukheki	80.0	20.0	60.0	40.0	20.0	40.0	40.0
Narowal	50.0	50.0	25.0	75.0	25.0	25.0	50.0
Depalpur	75.0	25.0	50.0	50.0	12.5	12.5	75.0
Manga mandi	60.0	40.0	80.0	20.0	20.0	20.0	60.0
Changa Manga	40.0	60.0	60.0	40.0	20.0	–	80.0
Kot Radha Kishen	37.5	62.5	62.5	37.5	12.5	12.5	75.0
Kasur	55.6	44.4	66.7	33.3	11.1	11.1	77.8
Sheikhupura	57.1	42.9	71.4	28.6	14.3	–	85.7
χ^2	16.146		18.667		17.229		
p-value	0.241		0.134		0.902		

Table 8
Production analysis of broiler farms located at different areas of Punjab, Pakistan.

Area	N	Market age (d)	Body weight (Kg)	Mortality (%)	FCR	Adj FCR
Multan	8	$36.94^{g} \pm 0.54$	2.34 ± 0.04	4.55 ± 0.60	$1.45^{k} \pm 0.01$	$1.37^{h} \pm 0.01$
Okara	10	$40.05^{cdef} \pm 0.67$	2.31 ± 0.05	3.74 ± 0.26	$1.49^{j} \pm 0.00$	$1.42^{gh} \pm 0.01$
Sahiwal	10	$37.55^{efg} \pm 0.41$	2.28 ± 0.04	4.48 ± 0.61	$1.53^{hi} \pm 0.00$	$1.47^{fg} \pm 0.01$
Depalpur	8	$39.88^{cdefg} \pm 0.91$	2.28 ± 0.07	4.59 ± 0.87	$1.62^{f} \pm 0.00$	$1.56^{d} \pm 0.01$
Sargodha	7	$40.50^{bcde} \pm 0.87$	2.38 ± 0.03	6.55 ± 1.16	$1.56^{gh} \pm 0.00$	$1.48^{efg} \pm 0.01$
Burewala	7	$37.12^{fg} \pm 0.53$	2.32 ± 0.05	4.85 ± 0.76	$1.50^{ij} \pm 0.00$	$1.44^{g} \pm 0.01$
Vehari	7	$38.31^{defg} \pm 0.38$	2.31 ± 0.06	4.87 ± 0.85	$1.52^{ij} \pm 0.00$	$1.45^{fg} \pm 0.01$
Sheikhupra	7	$44.29^{a} \pm 1.82$	2.20 ± 0.09	8.81 ± 5.85	$1.92^{a} \pm 0.05$	$1.87^{a} \pm 0.06$
Manga mandi	5	$41.60^{abc} \pm 1.17$	2.21 ± 0.04	6.02 ± 1.93	$1.66^{e} \pm 0.01$	$1.62^{c} \pm 0.01$
Kot Radha Kishen	8	$43.38^{ab} \pm 0.96$	2.15 ± 0.06	4.58 ± 1.28	$1.77^{c} \pm 0.01$	$1.73^{b} \pm 0.02$
Changa Manga	5	$41.60^{abc} \pm 0.93$	2.12 ± 0.04	6.59 ± 1.96	$1.70^{d} \pm 0.01$	$1.67^{c} \pm 0.02$
Kasur	9	$44.33^{a} \pm 1.11$	2.21 ± 0.06	7.89 ± 2.65	$1.81^{b} \pm 0.01$	$1.77^{b} \pm 0.02$
Narowal	4	$40.63^{bcde} \pm 1.18$	2.26 ± 0.07	3.60 ± 0.22	$1.59^{fg} \pm 0.00$	$1.54^{de} \pm 0.02$
Sukheki	5	$40.90^{bcd} \pm 1.14$	2.37 ± 0.08	3.18 ± 0.10	$1.58^{fg} \pm 0.00$	$1.51^{def} \pm 0.02$
p-value		<0.0001	0.083	0.7720	<0.0001	<0.0001

Superscripts on different means within column differ significantly at $p \leq 0.0$.

In Pakistan, mostly four major broiler strains (Cobb 500, Ross 308, Arbor acres, Hubbard Classic) were being raised. Due to the traits that farmers preferred, these four strains dominated the market. The grandparents, which are imported by large investors such as Big Bird group, K&N's, and Jadeed etc., reproduce and hatch to provide breeder stock which produce commercial broilers that are raised for consumption [2]. Similarly, commonly reared broiler strains observed in this study included Cobb 500, Ross 308, Arbor Acre, and Hubbard Classic. It was observed that Cobb 500 and Ross 308, both had more bone-to-meat ratios than other strains. Furthermore, these strains had a higher number of grandparent flocks in Pakistan that ultimately increase their share in the market. It has been observed that carcass composition can be modified by age, sex, and breed [28]. In many studies, female broiler chickens demonstrated a higher proportion of breast meat than males, while their proportion of leg and thigh meat was lower compared to males [29]. Moreover, in another study, Cobb 500 showed better immune responses against Newcastle disease vaccine than other strains [30].

The modern trend of ECH and the motivation and competition among the farmers are also leading toward the best infrastructure. Personnel protective equipment (i.e., shoes and clothing) are primary vectors when entry is permitted onto the farm, making foot dips essential. Additionally, the sanitary zone plays a crucial role in minimizing disease transmission within the farm premises. In the current study, this is a positive step towards the better performance of flocks and showing the farmer's education and knowledge about the importance of biosecurity. There are three elements of biosecurity protocol at poultry premises; first segregation and traffic control, second cleaning and third disinfection. The contacts and movement at farms are included in the first element "segregation and traffic control" [31]. This study exhibited that in majority of the broiler farms well-developed housing infrastructure was observed including foot dips, washing areas, fencing around farms, secured housing to protect against wild birds and animals, and rat traps. The fencing and secure housing are important to control the wild birds, animals, or even un-wanted personnel/vehicle crossing the farm area because these are responsible for several infections like Salmonellosis and influenza virus infection. However, cats are the potential source of *Pasteurella multocida* and *Toxoplasma gondii* infection in chickens [32]. In Italy, it was found that the majority of the poultry farms (>70 %) had satisfactory levels of compliance with external biosecurity protocols including farm environment hygiene and farm infrastructure with cleaning/disinfection practices. So, the study revealed that almost >60 % of farms followed the external biosecurity practices properly to comply with the infections [33]. Extremely variable environmental factors, such as poor management, insufficient ventilation, high stocking densities, poor litter conditions, and poor hygiene, have an impact on the disease's severity, duration of onset of disease, and death [34]. The annual cycles of broiler production are affected by the length of downtime period and length of production period [35]. Wild birds or animals and rodents are the vectors of disease transfer among flocks [31]. The cats, dogs and rats mostly breach the biosecurity and create an alarming phase of disease sometimes if not controlled. The prevalence of thermophilic campylobacter strains with high levels of resistance in wild birds suggests that this source may be crucial for the spread of resistant campylobacter and its potential transmission to humans, livestock, poultry and other sources [36].

The best protocol is dry cleaning, wet cleaning, and disinfection and the survey indicated that this method was more prevalent, attributed to the greater number of environmentally controlled houses and the presence of knowledgeable staff. Cleaning and disinfection are the main tools for the new flock performance in regards to biosecurity elements [31]. The cleaning normally includes dry and wet cleaning with any detergent. The disinfection is done after the cleaning with water. Zoonosis and animal infections can be prevented by following the cleaning and disinfection protocols correctly between production cycles and using suitable products [36]. In this study, it was noted that most of broiler farms practicing dry cleaning followed by washing with chlorinated water and detergent. In some farms, formalin solution and liquid soap spray were used for cleaning. Additionally, other farms employed Virkon (potassium peroxymonosulfate) spray along with intra multi des GA and a combination of liquid soap and caustic soda. This study showed that the majority of the farms in Punjab have birds of the same age across one or more sheds, while some farms have multi-age flocks across different sheds. Study suggested that the all-in-all-out system is responsible for less occurrence of diseases like swollen head syndromes in broiler flocks [37].

Regarding water quality, two main factors Total Dissolved Solids (TDS) and pH are considered at broiler farms. TDS are not directly linked to any poultry health issues, but equipment function and water delivery could be negatively affected by total solids. A good TDS level for poultry is recommended in a range of 0–1000 mg/L and the 1000–3000 mg/L range is considered satisfactory [38] whereas a pH range of 6.5–8.5 is recommended for poultry [38]. In this study, TDS levels (mg/L) in drinking and cleaning water in majority of broiler farms were around 701–900 and pH vary from 7 to 8; meaning that most farms in Punjab are good for poultry in terms of good quality drinking and cleaning water having TDS and pH in normal range.

At the production facility, birds are the primary assets, received at the start of the production cycle and depopulated at market age. Proper timing, protocols, and practices should be implemented to ensure efficient and effective management of production. Both practices are deemed beneficial because the availability of transportation or labour, the travel situation, and the area requirements are crucial factors in determining the timing for farmers. At the end of rearing period, the birds' sale is a very important step for poultry producers. In this study, it was noted that veterinarians visit broiler farms frequently with strict biosecurity measures. The supply of feed and litter among different broiler farms was typically checked before every flock (more than 60 % of the time) and also on a monthly basis (over 30 % of the time). This shows that most farmers have awareness of traffic control at the farm level to maintain and improve production. Farmers remove mortalities daily and dispose of them in a designated pit and the waste from the pits is cleared in 3–4 days as mortality is the main factor that causes fluctuations in the revenue of poultry farm percentage. Disposal of dead birds on the farm continues to be a challenge from the standpoints of cost, environmental safety and biosecurity. These dead birds may contain different viral and bacterial infection-causing germs hence their disposal is important [2]. In case of any viral attack mortality rate increases in poultry. Pit disposal method is mostly preferred as it is easy to manage than composting. The personnel that visit the farm can carry the pathogens from one poultry facility to another [2].

In this study, it was noted that broiler farms in the Sheikhupura and Kasur regions had the longest market age (44 days), whereas the shortest market age (37 days) was recorded in Multan. The market age of the broiler is very important in terms of economics, if

broiler chickens are kept in the shed beyond their desired body weight, they may continue to consume feed without adding to their body mass. This can lead to inefficient use of feed, as the additional feed consumed does not contribute to further growth [39]. The body weight of broilers is an important factor in the poultry meat industry because the carcass and its cut-ups are valuable with massive weight. The consumers also like this type of carcass at the time of purchase. However, in current study there were no significant differences in broiler body weight or mortality rates across the various regions of Punjab, Pakistan. Broilers growth, weight gain and FCR are directly influenced by production factors such as feedstuffs, labour, equipment, environment, production methods, and measurement accuracy [40]. The FCR values are crucial for analysing flock performance and representing production efficiency and main concern of farmers. In present study, the district of Multan in Punjab, Pakistan, exhibited the most favourable FCR and adjusted FCR values compared to other areas. This superiority can be attributed to the widespread use of environmentally controlled sheds in Multan, along with the effective implementation of biosecurity practices by farmers in the region. The poor values of FCR were observed in Sheikhupura and Kasur areas due to low biosecurity tools and poor managemental practices among different areas of Punjab, Pakistan. Similarly, in other study reported better feed efficiency of commercial broiler chicken which were raised in the Okara region compared to birds located in different region of central Punjab [2]. As Okara is located in the same belt where Multan region exist, therefore, most likely explanation of better performance of broiler flock in this study might be due to better suitability acclimatization of birds.

5. Conclusions

The findings of this study indicate that effective management practices are widely implemented on broiler farms across Punjab, Pakistan, contributing to improved performance and better health status of the birds. However, future studies should focus on further exploring this area and developing strategies to address potential challenges faced by poultry farmers.

CRediT authorship contribution statement

Muhammad Tahir Amin: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Muhammad Usman:** Writing – review & editing, Supervision, Conceptualization. **Hafiz Muhammad Ishaq:** Writing – review & editing. **Asad Ali:** Supervision. **Muzamal Tariq:** Methodology, Data curation. **Mian Mubashar Saleem:** Methodology, Data curation. **Syed Ghulam Mohayud Din Hashmi:** Software. **Kinza Saleem:** Writing – review & editing, Visualization, Conceptualization. **Sohail Ahmad:** Writing – review & editing, Supervision, Funding acquisition, Formal analysis, Conceptualization.

Data availability statement

Data were not deposited into a publicly available repository and will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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