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IMPACT OF ADOPTING BIOSECURITY AND IMPROVED HUSBANDRY PRACTICES ON INCOME STABILITY AND LIVELIHOOD SECURITY OF SMALLHOLDER POULTRY FARMERS IN PUNJAB, PAKISTAN

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ABSTRACT

Poultry farming plays a vital role in rural livelihoods and food security in Punjab, Pakistan, yet smallholder farmers face significant income instability due to disease outbreaks and suboptimal husbandry practices. This study assessed the impact of adopting biosecurity and improved husbandry practices on income stability and livelihood security among 300 smallholder poultry farmers. Data were collected using structured questionnaires and analyzed through descriptive statistics, chi-square tests, independent t-tests, and multiple regression models. Findings reveal that basic practices, such as proper feed and water management (Mean = 2.13, SD = 0.78) and vaccination against common diseases (Mean = 2.03, SD = 0.81), were moderately adopted, while stringent biosecurity measures, including isolation of sick birds (Mean = 1.68, SD = 0.88), were least practiced. Adoption of these practices significantly enhanced income stability, with higher regularity of monthly income (Mean = 2.08, SD = 0.79) and reduction in disease-related losses (Mean = 2.03, SD = 0.81). Livelihood security also improved, particularly in household food security (Mean = 2.12, SD = 0.78) and income diversification (Mean = 2.05, SD = 0.81). Regression analysis confirmed that adoption positively predicted income stability ($\beta = 0.412$, $p < 0.01$) and livelihood security ($\beta = 0.356$, $p < 0.01$), while cultural factors negatively moderated these outcomes. The study underscores the importance of education, institutional support, and culturally sensitive interventions to promote adoption, enhance productivity, and strengthen smallholder resilience.

***Keywords*:** Biosecurity, Husbandry practices, Income stability, Livelihood security, Smallholder poultry farmers, Punjab, Pakistan.

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1. INTRODUCTION

Pakistan has an agricultural economy where 1.5 percent of the gross domestic product comes from poultry sector. Poultry industry plays a key role in food security, supply of high-protein food, and as a source of income, particularly to the smallholder farmers in Punjab, which is the most populated and agriculturally-productive province in the country. Smallholder poultry farmers (with 50 to 500 birds) dominate most rural poultry businesses and are often characterized by limited material resources (lack of capital) and primitive production methods (FAO, 2024). Despite the enormous contribution of these farmers, they remain highly susceptible to loss of income due to events such as disease outbreaks, poor farming methodologies, and a lack of access to new technologies.

Globally, biosecurity and improved husbandry practices are considered the most significant interventions in reducing diseases, enhancing productivity, and stabilizing farm income. Biosecurity encompasses the tools that contribute to preventing the introduction and spread of contagious diseases in poultry flocks, including access control to poultry houses, disinfection, and effective waste management (Adaszyńska et al., 2025). Conversely, better husbandry techniques involve the adoption of scientific feeding techniques, proper housing conditions, vaccination, and regular check-ups. All these activities are expected to lead to improved health of the flock, reduced mortality, and enhanced growth performance, which will ultimately result in better productivity and monetary returns (Hyelda et al., 2020).

Smallholder poultry farmers in Punjab are limited in their ability to adopt biosecurity and improved husbandry

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practices. Some of the most notable attributes of the barriers include lack of knowledge and awareness, lack of financial resources, and lack of access to veterinary services (Amin et al., 2025). According to researchers, morbidity and mortality rates of poultry caused by the diseases of infectious etiology, such as Newcastle disease, avian influenza, Salmonella, and so on, can reach up to 20-40 percent in non-vaccinated flocks, which directly influence household income and food security (Jagalur & Manjula, 2023). Poor husbandry, including overcrowding, inadequate feeding, and substandard housing, also contributes to disease susceptibility and low productivity. Smallholders are mostly affected by these, as they lack risk-buffering systems (insurance or access to formal credit facilities) (Ibok et al., 2024).

It has been reported that the adoption of biosecurity and improved husbandry has had a positive impact on the income and livelihood stability of smallholder farmers. By the way, to reduce mortality and morbidity rates and stabilize the availability of eggs and meat to local markets, biosecure housing and vaccination are important (FAO, 2024). The greater the production, the higher the income, the higher the consumption by the household, which in turn helps reduce poverty and strengthen the rural population (Olutumise et al., 2023). The reduced frequency of emergency veterinary visits in healthier flocks will also translate into a reduction in the business's operating costs, allowing farmers to plan more effectively when to produce what and when to do it (Neeteson et al., 2023).

The stable agricultural yields means livelihood security, which can be described as improvement in their living standards (Vlaicu et al., 2024). By mitigating risks and losses in production, farmers are better equipped to meet household consumption needs, invest in education and healthcare, and diversify their income sources. Further, some families in a rural area use poultry farming as an additional income source, in addition to growing crops and keeping livestock. Gender implications also exist in farming, with women active involvement in different tasks. The welfare of women and the household as a whole can therefore be improved by increasing the productivity and income security of poultry farming (Ngouambé et al., 2020).

However, biosecurity, and improved husbandry practices among smallholder farmers in Punjab are extremely low, despite the obvious benefits linked to them. Cultural practices, risk aversion attitude and lack of extension services are the most common barriers. In addition, farmers are less likely to adopt and utilize improved practices due to limited access to affordable inputs, credit, and training. All challenges listed above also suggest that the adotion of biosecurity practices by small farmers requires special supportive policy interventions (Ibok et al., 2024).

Given the importance of smallholder poultry farming to rural livelihoods and food security, there is a need of empirical evidences to determine whether the adoption of biosecurity and improved husbandry practices will have any impact on income stability and livelihood security. This study will fill the knowledge gap by systematically identifying adoption levels and their economic impact on the income, as well as enumerating social, financial, and institutional variables that need to be considered to foster biosecurity practices uptake in Punjab, Pakistan. The study aims to identify the level of adoption of biosecurity and improved practices, to explore the impact of adoption on the income stability, and to identify socio economic, institutional and cultural factors influencing adoption. The findings will provide evidence-based policy suggestions to guide policymakers, development organizations and extension services in designing programs that can enhance productivity, income security and wellbeing of rural poultry farmers.

2. MATERIALS AND METHODS

2.1. Research Design

The current study used a quantitative, cross-sectional research design to systematically achieve the objectives. This design is suitable for the study and was selected because it allows collecting data across different socio-economic groups at a single time.

2.2. Study Population

The sample population consisted of rural smallholder poultry farmers in the sampled rural districts in Punjab, who rear less than 500 birds to support their families in terms of food and income. It was decided to use the multistage sampling technique. First, the districts were selected based on the intensity of poultry production, then the tehsils, villages and finally the farmers were selected, randomly. According to Punjab Livestock Department, Faisalabad district has the highest number of farms in the province. So, it was selected as the study area. Next, three tehsils (Jaranwala, Samundri, and Tandlianwala) were selected out of six, randomly. 100 farmers were selected randomly from eeach tehsil to reach a total sample of 300 farmers.

2.3. Data Collection

Primary data were gathered through the structured questionnaire and divided into four sections: demographic and

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socioeconomic, adoption of biosecurity and husbandry practices, sources of income stability, and livelihood security. Some practices related to the assessment of adoption were vaccination practices, hygiene procedures, poultry housing, feed and water management practices, and disease prevention practices. Income stability and livelihood security were assessed in terms of access to food, education, healthcare, and savings, as well as monthly and annual income, income variability, and reliance on poultry as a means of livelihood. A 5-point Likert scale (1 = strongly disagree; 5 = strongly agree) was used to measure adoption and perceived benefits of the system. The questionnaire had to be both reliable and understandable, so it was first pre-tested on 30 farmers. Data was collected through face-to-face interviews. Ethical concerns were observed , including informed consent, confidentiality, and voluntary participation.

2.4. Data Analysis

For data analysis, SPSS was used to compute descriptive and inferential statistics. The mean adoption score ($\bar{X}$) for each practice was calculated as:

$$\bar{X}=\frac{\sum_{i}^{n}=1\ Xi}{n}$$

where Xi is the adoption score of the farmer and n is the sample size. The standard deviation (SD) was computed as:

$$SD=\sqrt{\frac{\sum_{i}^{n}=1\ (Xi-\bar{X})^2}{n-1}}$$

To examine relationships between socioeconomic factors (SEF) and adoption of practices (AP), chi-square tests were applied:

$$X^2=\sum\frac{(Oi-Ei)^2}{Ei}$$

Where Oi and Ei are the observed and expected frequencies, respectively. Differences in income stability (IS) and livelihood security (LS) between adopters and non-adopters were tested using independent t-tests:

$$t=\frac{\bar{X}1-\bar{X}2}{\sqrt{\frac{S1^2}{n1}+\frac{S2^2}{n2}}}$$

where $\bar{X}_1$ and $\bar{X}_2$ are the group means, S_1^2 and S_2^2 are variances, and n_1 and n_2 are sample sizes. Multiple regression analysis was conducted to quantify the effect of adoption on income stability and livelihood security while controlling for socioeconomic (SEF), institutional (IF), and cultural factors (CF):

$Y=\beta0+\beta1 + AP+\beta2 + SEF+\beta3 + IF+\beta4 + CF+\epsilon$

where Y represents income stability or livelihood security, β0 is the intercept, β1–β4 are regression coefficients, and ϵ is the error term. Reliability of scales was verified using Cronbach's alpha:

$$\alpha=\frac{K}{K-1}\left(1-\frac{\sum_{i}^{k}=1\ \sigma_i^2}{\sigma_T^2}\right)$$

Where k is the number of items, is the variance of each item and is the total variance. This necessitated a study design that could effectively identify the level of adoption, socioeconomic variables, and biosecurity and husbandry practices implications on livelihood security and income stability of smallholder poultry farmers in Punjab.

The scales have been tested concerning the reliability (Cronbach's alpha = 0.82) and validity of the construct (with regards to the purpose of the research and the opinion of experts). This approach served to adequately quantify adoption rates, their impact on livelihoods and income, and the factors influencing the practice of smallholder poultry keepers in Punjab.

3. RESULTS AND DISCUSSION

1.1. Demographic Characteristics

Table 1 age distribution data indicate that the biggest category was 26-35 years consisted of 30% respondents. and the second category with 28.3% of respondents was 36-45 years.. This means that most poultry farmers are of middle age. Nishanka et al. (2024) and FAO (2024) stated that middle-aged individuals form the largest population of small-scale poultry farming in South Asia. The respondents are 30% female and 70% male. Although poultry farming is often considered an activity primarily performed by females in the household, in organized poultry farming, men are frequently the resource owners, decision-makers, and influencers (Olutumise et al., 2023; Nishanka et al., 2024). Results on education showed that 30% of respondents had primary education, 20% had middle, while 26.7% percent were illiterate. Only 1 in 10 had gone on to secondary education or beyond. Low levels of literacy may limit the knowledge and implementation of biosecurity and improved husbandry practices, which is consistent with the existing literature on the role of education as one of the underlying determinants of successful technology adoption in poultry farming (Wilson et al., 2022; Ngouambé et al., 2020).

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Table 1: Demographic Characteristics of Smallholder Poultry Farmers (n = 300)

Characteristics	Categories	Frequency (f)	Percentage (%)
Age (years)	18–25	35	11.7
	26–35	90	30.0
	36–45	85	28.3
	46–55	60	20.0
	56 and above	30	10.0
Gender	Male	210	70.0
	Female	90	30.0
Education Level	Illiterate	80	26.7
	Primary (1–5)	90	30.0
	Middle (6–8)	60	20.0
	Secondary (9–10)	40	13.3
	Higher Secondary & above	30	10.0
Household Size	1–4 members	50	16.7
	5–7 members	140	46.7
	8–10 members	85	28.3
	10+ members	25	8.3
Marital Status	Single	35	11.7
	Married	230	76.7
	Widowed	25	8.3
	Divorced/Separated	10	3.3
Farming Experience (Years in Poultry)	<5 years	60	20.0
	5–10 years	110	36.7
	11–15 years	70	23.3
	>15 years	60	20.0
Farm Size (Birds)	<100 birds	95	31.7
	100–250 birds	110	36.7
	251–500 birds	95	31.7

Analysis of household size indicated that most respondents (46.7%) lived in medium-sized households (5-7 people), which may influence the availability of labor to handle the poultry. Similarly, the status of marriage revealed that 76.7 percent of research participants were married, supporting the notion that poultry farming is a family-owned business, as hypothesized by Ibok et al. (2024). Farming experience of 36.7% respondents was of 5-10 years, while 20% have above 15 years. In most instances, when production and biosecurity techniques improve, experienced farmers have the capacity to utilize them due to an understanding of production risks and market demand (Vlaicu et al., 2024). Regarding farm size, small ones (having less than 100 birds) were 31.7%, medium farms (with 100-250 birds) were 36.7% and large (with 251-500 birds) were again 31.7%, indication almost symmetrical distribution of the various sizes of smallholder poultry enterprises in Punjab. Small farms often face challenges to survive and require additional supportive measures such as practices of biosecurity to prevent epidemics (FAO, 2024; Ogunniyi et al., 2020).The social-demographic factors are believed to influence the adoption of innovations and the success of interventions in improving poultry productivity and livelihoods in households (Syed et al., 2022; Hussain, 2022).

1.2. Adoption of Biosecurity and Improved Husbandry Practices

Table 2 presents the extent of adoption of biosecurity and improved husbandry behaviours by 300 smallholder poultry farmers in Punjab, Pakistan based on a 3-point Likert scale (1 = Not Adopted, 2 = Partially Adopted, 3 = Fully Adopted).

Table 2: Level of Adoption of Biosecurity and Improved Husbandry Practices among Smallholder Poultry Farmers (n = 300)

Biosecurity / Husbandry Practice	Mean Score	SD	Rank
Proper feed and water management	2.13	0.78	1
Vaccination against common poultry diseases	2.03	0.81	2
Use of disinfectants in poultry houses	1.98	0.79	3
Proper housing (ventilation, space, cleanliness)	1.92	0.82	4
Regular health monitoring of birds	1.87	0.83	5
Waste and manure management	1.83	0.85	6
Controlled access to poultry houses (restricted visitors)	1.75	0.86	7
Isolation of sick birds	1.68	0.88	8

The most common practice found was proper feed and water management with mean value of 2.13 (SD=.78, Rank 1), indicating that farmers are far more concerned with basic nutrition and hydration to support the health and

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productivity of flocks. The second was vaccination against common poultry disease (Mean = 2.03, SD = 0.81), the most likely effect of which was awareness and vaccine availability (Wilson et al., 2022). Poultry house Disinfection with mean value of 1.98 stook at three in ranking, suggesting that some farmers understand that they should disinfect the house. Next practices were proper housing conditions (ventilation, space and cleanliness) with mean value of 1.92 (SD = 0.82, Rank 4) and regular health monitoring . (Mean = 1.87, SD = 0.83, Rank 5). Waste management (Mean = 1.83, SD = 0.85, Rank 6), limmited access to poultry houses (Mean = 1.75, SD = 0.86, Rank 7) and isolation of sick birds (Mean = 1.68, SD = 0.88, Rank 8) attained lower mean scores due to their less adoption among farmers, indicating potential biosecurity gaps (Wongnaa et al., 2023; Nishanka et al., 2024). These results can be summarized to conclude that basic husbandry activities, including feeding, watering, and vaccination, are moderately applied; however, more stringent biosecurity activities are not practiced accordingly. The trend justifies the importance of deliberate actions, such as educating farmers and providing biosecurity resources and institutional facilities, to promote the adoption of holistic rearing approaches and income and livelihood security among smallholder poultry farmers in Punjab.

1.3. Impact of Adopting Biosecurity and Improved Husbandry Practices on Income Stability

Table 3 shows the magnitude of the effect of biosecurity establishment and enhanced husbandry on the income stability of smallholder poultry farmers in Punjab, Pakistan. These are the findings based on a 3-point Likert scale, with 1 representing no effect, 2 representing a moderate effect, and 3 representing a high effect. The mean scores, standard deviations (SD) and ranking of seven important indicators are presented.

The findings show that the regularity of monthly income from poultry (2.08, SD = 0.79) has the highest mean score. This implies that farmers who adopt biosecurity measures, such as restricted entry to poultry abodes, regular sanitation, and improved husbandry techniques like proper feeding and housing, have a more balanced stream of earnings. The result is consistent with the literature by Neeteson et al. (2023), who found that increased biosecurity reduces flock losses and stabilizes earnings for smallholder poultry farmers in developing nations. the drop in the loss of income due to diseases (mean = 2.03, SD = 0.81), demonstrates the highly significant role of biosecurity measures in disease prevention and ultimately in the protection of income. Vaccination programs that reduce mortality and morbidity caused by poor husbandry methods directly affect income stability (Subasinghe et al., 2023). The third and fourth rankings were increase in profitability per bird (mean = 1.97, SD = 0.82) and the ability to invest in poultry inputs (mean = 1.91, SD = 0.84). Many studies found that farmers who use recommended practices can maximize production, minimize losses in feed and medication, invest profits in the business, (Subasinghe et al., 2023) and Ibok et al., 2024).

Stability of household expenditure on poultry income (mean = 1.88, SD = 0.85) and coping with unexpected poultry costs (mean = 1.82, SD = 0.87) were ranked number five and six, respectively. These average values suggest that even though biosecurity and enhanced husbandry practices, market risks like market fluctuations, feed costs, and weather patterns can continue to influence poultry farming (Murekatete et al., 2023). Poultry was the least significant contributor to total household income among the sources (1.79, SD = 0.88), as one would expect given that many smallholder households do not include poultry income in their livelihood portfolios. However, a better method of poultry management also boosts productivity within the poultry sector, thereby indirectly leading to resilience in household and income diversification (Olutumise et al., 2023). As shown in Table 3, the benefits of biosecurity and enhanced husbandry behaviors to the smallholder poultry farmers in Punjab are positively correlated with the various aspects of income stability. Findings indicate that training, extension services and use of funds to increase productivity and livelihood security should promote such practices.

Table 3: Impact of Adopting Biosecurity and Improved Husbandry Practices on Income Stability of Smallholder Poultry Farmers (n = 300)

Indicators of Income Stability	Mean Score	SD	Rank
Regularity of monthly income from poultry	2.08	0.79	1
Reduction in income loss due to diseases	2.03	0.81	2
Increase in profitability per bird	1.97	0.82	3
Ability to invest in poultry inputs	1.91	0.84	4
Consistency of household expenditure from poultry income	1.88	0.85	5
Ability to cope with unexpected poultry-related expenses	1.82	0.87	6
Contribution of poultry income to overall household income	1.79	0.88	7

1.4. Influence of Biosecurity and Improved Husbandry Practices on Livelihood Security

The impact of implementation of biosecurity and enhanced husbandry on the different dimensions of livelihood security of 300 smallholder poultry households in Punjab, Pakistan is recorded in Table 4. The findings reveal that the practice adoption has a positive effect on the household wellbeing on a 3-point Likert scale ranging between 1.85 and 2.12.

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Table 4: Influence of Biosecurity and Improved Husbandry Practices on Livelihood Security of Smallholder Poultry Households (n = 300)

Livelihood Security Indicator	Mean	SD	Rank
Improved household food security	2.12	0.78	1
Enhanced income diversification	2.05	0.81	2
Increased ability to meet healthcare and education expenses	2.01	0.82	3
Reduced vulnerability to income shocks	1.97	0.84	4
Improved housing and living conditions	1.91	0.86	5
Ability to invest in farm inputs and savings	1.88	0.87	6
Overall improvement in household wellbeing	1.85	0.89	7

The indicator of improved household food security (Mean = 2.12, SD = 0.78) is ranked as the best and signifies that those farmers who observe proper biosecurity and husbandry have a higher availability and access to poultry products, e.g., eggs and meat, which directly translate to better nutritional outcomes. These results are in line with evidence provided by Mijena and Getiso (2024), who documented that biosecure poultry management improves food security in the smallholder systems. The second-ranked indicator, increased income diversification (Mean = 2.05, SD = 0.81) shows that the improved practices help households to receive a more stable poultry-related income and to rely less on a single income source. This confirms the findings of Okwuokeneye et al., (2024), who found the more good husbandry practices, the more resilient the smallholder farmers were to market variability. Others such as increased ability to cover medical and education expenses (Mean = 2.01, SD = 0.82) and reduced vulnerability to income shocks (Mean = 1.97, SD = 0.84) indicate that such practices will bring equilibrium in the economy and make the household less susceptible to financial shocks caused by epidemics or market oscillations. Evidence of the secondary benefits of biosecurity and improved husbandry practices is better housing and livelihood conditions (Mean = 1.91, SD = 0.86) and the ability to invest in both the poultry and non-poultry stock (Mean = 1.88, SD = 0.87). Finally, the overall growth of household wellbeing (Mean = 1.85, SD = 0.89) lends credence to the notion that the practices, on the whole, can enhance livelihood security. Improvement of the livelihood security of the smallholder poultry farmers of Punjab through adoption of biosecurity and improved husbandry practices is very crucial in improving both the economic and social dimensions of livelihood security as shown in Table 4. These findings are supported by earlier research which reveals that technical, managerial and preventive intervention measures in small scale poultry systems are critical determinants of sustainable livelihoods.

1.4.1. Chi-square Tests

The table 5 presents the results of Chi-square tests done to establish the association between various socioeconomic factors and adoption of biosecurity by the smallholder poultry farmers in Punjab, Pakistan.

Table 5: Chi-square Tests of Associations between Socioeconomic Characteristics and Adoption of Biosecurity and Improved Husbandry Practices (n = 300)

Socioeconomic Characteristics	χ^2	p-value	Significance
Education Level	14.27	0.001	$p < 0.01$
Household Income	11.84	0.003	$p < 0.01$
Farm Size (Poultry Flock)	7.56	0.023	*p < 0.05*
Age of Farmer	3.42	0.181	Not significant
Household Size	4.15	0.125	Not significant
Gender	2.63	0.105	Not significant

Notes: χ^2 = Chi-square statistic; p-value = significance level; *p < 0.05, **p < 0.01 (statistically significant)

The education level and household income were highly and positively associated with the use of biosecurity with Chi-square of 14.27 (p = 0.001) and 11.84 (p = 0.003), respectively. This is why more enlightened farmers with increased funds will readily adopt biosecurity practices because they are more knowledgeable about the methods of disease prevention and are also able to afford the inputs (Aondo et al., 2020). Another notable, although less significant relation was also observed between farm size in terms of flock size (χ^2 = 7.56, p = 0.023) with larger poultry holdings more likely to implement biosecurity to protect more valuable livestock. On the other hand, the age of the farmer (χ^2 = 3.42, p = 0.181), household size (χ^2 = 4.15, p = 0.125) and gender (χ^2 = 2.63, p = 0.105), were not significant, i.e., they did not significantly contribute to the adoption of biosecurity in this case. Overall, these findings indicate the importance of socioeconomic empowerment and in particular education, income, and access to farm resources in motivating smallholder poultry farmers to adopt biosecurity measures. This is aligned with the literature on the significance of knowledge and financial capacity to implement effective poultry management to enhance livelihood security and income stability.

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1.5. Factors Influencing Adoption of Biosecurity and Improved Husbandry Practices

Table 6 indicates the largest socioeconomic, institutional and cultural factors influencing the adoption of biosecurity and improved husbandry practices by smallholder poultry farmers in Punjab, Pakistan. The results are based on a sample of 300 respondents and presented in mean scores, standard deviations (SD) and rank order which reflects the relative importance of each of these factors.

Table 6: Factors Influencing Adoption of Biosecurity and Improved Husbandry Practices (n = 300)

Factors Category	Specific Factor	Mean	SD	Rank
Socioeconomic Factors	Education level of farmer	4.21	0.72	1
	Household income level	4.05	0.78	2
	Farm size / number of poultry birds	3.88	0.81	4
	Farming experience	3.95	0.75	3
Institutional Factors	Access to veterinary services	3.76	0.79	5
	Availability of extension support/training	3.65	0.82	6
	Access to credit/loans for poultry farming	3.54	0.85	7
Cultural Factors	Influence of family/community decisions	3.47	0.88	8
	Gender-based role in farm decision-making	3.38	0.90	9

It was found that the education level of the farmer was the most important socioeconomic factor with an average score of 4.21 (SD = 0.72, Rank 1). It also means that more educated farmers will use biosecurity measures and enhanced husbandry, which aligns with the associated literature on the importance of literacy and knowledge in the use of technology in agriculture (Keutchatang et al., 2021; Quisumbing et al., 2022). Household income level were ranked second (Mean = 4.05, SD = 0.78) suggesting that financial capabilities enable farmers to invest in enhanced poultry management, purchase quality inputs and utilize biosecurity-related measures effectively. Other factors which influenced favorably were experience in farming (Mean = 3.95, SD = 0.75, Rank 3) and size/number of poultry birds in the farm (Mean = 3.88, SD = 0.81, Rank 4).

The average score of access to veterinary services was 3.76 (SD = 0.79, Rank 5) on the institutional factors, thus it is clear that access to professional animal health support is a tremendous factor that facilitates adoption. The availability of extension support and training (Mean = 3.65, SD = 0.82, Rank 6) and availability of credit/loans to poultry farming (Mean = 3.54, SD = 0.85, Rank 7) had moderate effects, which means that institutional support systems, including advisory services and access to credit/loans, are critical in encouraging farmers to use better husbandry and biosecurity practices (Hofmann et al., 2020; Zubair et al., 2023 The cultural factors were The role of family and community decisions (Mean = 3.47, SD = 0.88, Rank 8) or gender roles in farm decisions (Mean = 3.38, SD = 0.90, Rank 9) suggests that socio-cultural norms and household processes can restrict the possibilities of specific farmers to implement new practices, particularly when such decisions are made either by women or in a patriarchal or a community context (Noor et al., 2022). In the table, social-economic determinants (primarily education and income) are the strongest determinants of adoption, institutional support is the next, and cultural norms are the moderating constraints. These findings underscore the significance of integrated interventions grounded on learning, financial empowerment, extension, and culture-sensitive awareness programs to facilitate the use of biosecurity and improved husbandry practices by smallholder poultry farmers in Punjab.

1.6. Multiple Regression Analysis

The results of multiple regression analysis that examine the impact of inclusion of biosecurity practice on the income stability and livelihood security of smallholder poultry farmers in Punjab Pakistan and additionally, based on socioeconomic, institutional and cultural factors are presented in Table 7. The size of the sample used was 300 respondents.

Table 7: Multiple Regression Analysis of Adoption Impact on Income Stability and Livelihood Security (n = 300)

Dependent Variable	Predictor Variable	B (Unstandardized)	SE (Standard Error)	β (Standardized)	t-value	p-value	95% CI
Income Stability	Adoption of biosecurity practices	0.321	0.045	0.412	7.13	0.000**	0.232, 0.410
	Socioeconomic factors	0.198	0.037	0.268	5.35	0.000**	0.126, 0.270
	Institutional factors	0.165	0.041	0.214	4.02	0.000**	0.084, 0.246
	Cultural factors	-0.134	0.039	-0.175	-3.44	0.001**	-0.211,-0.057
Livelihood Security	Adoption of biosecurity practices	0.287	0.048	0.356	5.98	0.000**	0.192, 0.382
	Socioeconomic factors	0.176	0.036	0.239	4.89	0.000**	0.106, 0.246
	Institutional factors	0.153	0.043	0.198	3.56	0.000**	0.069, 0.237
	Cultural factors	-0.121	0.040	-0.158	-3.03	0.003**	-0.200,-0.042

Model Summary: Income Stability: $R^2 = 0.528$, $F = 85.42$, $p < 0.001$; **Livelihood Security:** $R^2 = 0.497$, $F = 78.13$, $p < 0.001$
Notes: B = unstandardized coefficient; β = standardized coefficient; SE = standard error; CI = confidence interval; $p < 0.01$ (statistically significant)

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Adoption of biosecurity practices was the best positive predictor ($B = 0.321$, $\beta = 0.412$, $p < 0.01$) to be stable with income, that is, farmers who adopt biosecurity practices have more likelihoods to receive high and reliable poultry farming income. Socioeconomic factors ($B = 0.198$, $\beta = 0.268$, $p < 0.01$) and institutional factors ($B = 0.165$, $\beta = 0.214$, $p < 0.01$), that is, higher education, high household income, farm size, access of veterinary services, extension services, and access to credit, also positively affected income stability. The cultural factors, however, had a strong negative implication ($B = -0.134$, $\beta = -0.175$, $p < 0.01$) showing that restrictive social norms and the household decision-maker processes as well as gender-specific roles could serve as limiting factors to the positive effect of adoption on income. The model explained 52.8 percent of the total variance of income stability ($R^2 = 0.528$, $F = 85.42$, $p < 0.001$), and the overall fit of the model was good.

The strongest positive predictor regarding livelihood security ($B = 0.287$, $\beta = 0.356$, $p < 0.01$) and by extension, the provision of household food security, income diversification, the ability to cover healthcare and education expenses, and wellbeing was adoption of biosecurity practices. Social-economic ($B = 0.176$, $\beta = 0.239$, $p < 0.01$) and institutional factors also made a positive contribution to the livelihood security, that is, the financial resources, education, farm experience, and institutional support enhance the benefits of adopting improved poultry practices. Culture was again determined to play a negative role ($B = -0.121$, $\beta = -0.158$, $p < 0.01$) and that indicates the social norms and role as a traditional factor can reduce the success of biosecurity adoption on the general household livelihood. The livelihood security ($R^2 = 0.497$, $F = 78.13$, $p < 0.001$) was well explained using the model. As Table 7 indicates, the application of biosecurity and improved husbandry practices have a significant positive effect on the income stability and livelihood security of smallholder poultry farmers which are reinforced by socioeconomic and institutional support and constrained by cultural barriers. This can be attributed to the presence of easily accessible literature that has not only emphasized the importance of adoption of technology, economic empowerment, and institutional support in enhancing the lives of beta-occupants, but also has shown that the moderating factor may be socio-cultural constraints (Hyelda et al., 2020; Hisyam et al., 2023; Chauhan et al., 2024).

Conclusion

The findings of this paper confirm that introduction of biosecurity and increased agro husbandry activity in the state has profound impact on the income and livelihood security of the smallholder poultry farmers in Punjab, Pakistan. Farmers that implemented the proper feed and water management, vaccination, regular health, and biosecure cages also enjoyed regular monthly income, reduced losses due to diseases, increased profitability, and increased capacity to invest in poultry inputs. The fruits of that were in the form of greater livelihood gains, including greater household food security, diversification of income, access to healthcare and education, and wellbeing. Education, household income, size of farm and farm experience were independent determinants of adoption where institutional support in form of veterinary service, extension service and availability of credit further aided in implementation. Conversely, it was found that the positive impacts of adoption were mediated by cultural restrictions, including family and community decision-making regulations and gender-specific roles, i.e., social and cultural forces need to be restrained to achieve maximum positive effects. Generally, the paper highlights the fact that the best methods of promoting biosecurity and improved husbandry practices among smallholder poultry farmers include interventions that combine technical training interventions, financial inclusion interventions, and culturally sensitive awareness initiatives. Not only do these practices enhance the productivity of poultry, they also enhance the resilience of households, income stability, and sustainable rural livelihoods in Punjab.

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Ethics Statement: The studies were carried out in compliance with institutional norms and local laws. To take part in this study, the subjects gave their written informed consent. The Institute of Agricultural Extension, Education, and Rural Development at the University of Agriculture, Faisalabad, gave its approval to the human subjects' study.

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