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Research Article

Economic Impact of Novel and Emerging Genotype- XIII Newcastle Disease Virus Outbreak in Commercially Vaccinated Broiler Farms

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Abstract

Newcastle disease (ND) is one of the most devastating and contagious diseases of poultry caused by avian paramyxovirus-1 (APMV-1) which causes outbreaks in commercial poultry farms inspite of intensive vaccination throughout the world. Newcastle disease virus is a constantly evolving virus and cause outbreaks in commercial poultry farms throughout the world. Isolation of novel genotype-XIII-NDV from recent outbreaks in India shows emergence of new strains is limiting its diagnosis and control. India is the world's largest broiler meat producer and recent outbreaks have resulted in huge negative economic impact on the poultry industry; however, the economic impact of ND on poultry industry remains unclear and demands calculation of economic losses due to ND among the commercial vaccinated broiler farms in India. In the present paper economic losses among ten broiler farms were calculated where ND outbreak was reported despite of routine vaccination strategy. A new economic model was developed to calculate economic losses occurred due to mortality, vaccination, production lost (reduced body weight and increased FCR), treatment and biosecurity measures of individual broiler farms. Total economic losses in all the broiler farms were 5773978 Indian rupees (INR). Loss from mortality and reduced body weight contributed 1045983 and 3635904 Indian rupees (INR) out of total economic loss. Highest 62.97% and lowest 0.08% out of total economic loss was documented due to reduced body weight and vaccination measure. In India, ND poses a great threat to the commercial poultry industry inspite of stringent vaccination against ND. The data generated from this study will be valuable for assessing the global economic impact of Newcastle disease on the commercial broiler industry.

Keywords: Newcastle Disease; Indian Rupees; Genotype-XIII; Broiler; Economic Impact

Introduction

India ranks 3rd in Egg Production and 8th in meat production in the world consisting poultry market size of worth IN 1,905.3 billion in 2022 [1]. The poultry industry is further predicted to reach INR 3477 billion by 2028, expected to a growth rate (CAGR) of 10.18% during 2023-2028 [2]. Poultry constitutes the second-largest share of the livestock industry after pork, throughout the world, which would supersede all other livestock productions. In such situations, it becomes invariably important to cater the needs for sustainable development of poultry industry. Infectious diseases pose a major obstacle for poultry producers, as their presence in flocks has consistently been a key factor limiting profitable production [3]. Such diseases not only diminish trade and consumer confidence but also lead to legal trade restrictions, which result in long-term economic damage. Newcastle disease (ND) is an acute and highly fatal viral disease which affects a large number of domestic and wild bird species [4].

It is caused by virulent strains of avian paramyxovirus type 1 (APMV-1) [5], a negative-sense, single-stranded RNA virus belonging to the genus *Orthoavulavirus* in the family *Paramyxoviridae* [6]. Since its first identified in 1926, ND still poses a great economic threat to the poultry industry as it causes high mortality and production losses [7]. Despite conventional vaccination practices ND continues to cause outbreaks throughout the length and breadth of the country [8,9] and causes annual losses in millions of rupees [10]. In the last major outbreak of ND in the USA, the death of about 4 million birds caused a loss of approximately 162 million US dollars [11]. The continuous isolation of new genotypes in India highlights the evolving nature of the virus, with the emergence of new strains complicating diagnosis and control efforts. Based on phylogenetic analysis of partial hypervariable nucleotide sequences of the F gene, NDV strains have been classified into 18 genotypes (Class II, genotypes I to XVIII) [12]. During recent years, outbreaks of Newcastle disease in commercial broiler farms were observed inspite of the routine vaccination program in poultry farms around Anand, Gujarat state, India. The present work represents an overview of the neglected economic impact of this disease in the Indian subcontinent, more particularly in the western part of the country. No attempt has been made to calculate the economic losses due to ND among the commercial broiler chickens in India. Therefore, in the present study, we have calculated economic losses due to Newcastle disease.

Materials and Methods

Data methodology

Newcastle disease was reported in broiler farms around the Anand district of Gujarat, India inspite of the routine vaccination program. A total of ten broiler farms were reported with the condition. All reported outbreaks were confirmed through clinical signs, gross and histopathological examination of visceral organs, virus cultivation in egg embryos, and isolation of the virus via Haemagglutination (HA) and Haemagglutination Inhibition (HI) tests. The virulence of the virus was further assessed using the Intracerebral Pathogenicity Index (ICPI). Whole-genome sequencing of NDV isolates, including the F gene sequence, revealed a genome length of 15,192 nucleotides. The phylogenetic analysis and evolutionary distances assigned these isolates to Genotype XIII (XIIIb), based on the most recent available sequences in the gene bank.

A new and modified economic model, developed based on the earlier models was used to calculate economic losses [10,13]. The following approach was made to calculate estimated losses in broiler farms that occurred due to Newcastle disease around the Anand District of Gujarat state. During the study period following information was collected to make out economic loss. All the information regarding name and location of farm, flock strength, Age of the flock when N.D first detected, total no of bird died, overhead cost (included cost of electricity, management and labor) per chick per day (Rs), cost of day old chick (Rs), ND vaccination cost per chick (Rs), feed intake per chick (Rs), feed cost per kg (Rs), cost of medicine during outbreaks per chicks (Rs), other vaccination, medication and biosecurity measure cost per bird (Rs) and cost of per kg meat (Rs) described in Table 1. The lifespan of commercial broiler birds is 42-43 days we considered it as 42 days.

Economic models

Losses due to mortality: Losses due to mortality were calculated using the following formula.

$$LM = BD \times (VD + CCF + OC)$$

- LM = Loos due to Mortality
- BD = No of bird died
- VD = Value of day-old chicks

- CCF = Cost of cumulative feed consumed per bird upto a day before mortality
- OC = Overhead cost upto a day before mortality

The Cost of Newcastle disease vaccination: Losses due to vaccination did against NDV were calculated as follows.

LNV = NBV × CV

- LNV = Losses due to Newcastle disease vaccination
- NBV = No of birds vaccinated and died due to disease.
- CV = Cost of vaccine per dose

Loss due to biosecurity measures and other medication costs

TCBVM = BD × (CM + CV)

- TCBVM = Total cost of biosecurity, other vaccines and other medicines
- BD = Total birds died
- CM = Cost of medicine for prevention of other diseases
- CV = Cost of vaccine for prevention of other diseases

Losses due to medication during the outbreak

TCM = NTB × CM

- TCM = Cost of Medicine
- NTB = No. of birds treated
- CM = Cost of medicine per bird during outbreaks
- No birds treated (NTB) = Total No. of birds in the farm – No. of bird died.

Losses due to reduced body weight gain

TLRBG = NBAM X RBW X RM

- TLRBG = Total loss due to reduced body weight gain
- NBAM = No. broiler birds in the farms after mortality
- RBW = Reduced body weight gain (kg)
- RM = Rate of poultry meat (Rs/kg)
- RBW = Standard body weight – Actual body weight

Loss due to increase in FCR (Feed conservation ratio)

TLIFCR = NBAM X LB X Diff. FCR X CF

- TLIFCR = Total loss due to increased feed conversion ratio
- NBAM = No. of broiler birds on the farm after mortality
- LB = Live weight per bird
- Dif. FCR = Actual FCR – Standard FCR
- CF = Cost of broiler feed (Rs/kg)

Difference FCR and Difference Body weight (kg) documented in Table 2 and calculated with following formula:

Difference FCR = Actual FCR- Standard FCR

Difference Bodyweight = Standard Body weight at the day of termination of the flock – Actual body weight at the day of termination of the flock

During the study period, various types of information were collected to estimate economic losses and it was given in Table 1 and Table 2. The data used to evaluate losses due to Newcastle disease were gathered through personal communications with organized poultry farms and veterinary professionals involved in poultry disease diagnosis and management. The costs are presented in Indian Rupees (Rs) to provide a clearer understanding from an Indian perspective. Each parameter was analysed separately for each farm, with the associated costs calculated up to the day prior to mortality. These parameters varied depending on the specific management practices of each farm. The cost of medicine during outbreaks of all different farms was variable as using different drugs of the different companies. Other vaccination cost, biosecurity measures cost and other medication costs upto a day before mortality was variable as follow different management practices and using a different formulation of drugs of the different company.

Results

- **Loss from Mortality in broiler**: Mortality due to Newcastle disease in all the ten farms was ranged between 8 to 80 % (Table 1). Calculated economic loss of all ten broiler farms was described in Table: 3 and loss due to mortality ranged from 34080 to 213947 rupees (Table 3). Overall economic losses due to mortality were 1045983 rupees and it contributed

18.12 % out of total economic loss. The appearance of an outbreak at an early age resulted in heavy economic loss. The death was reported daily without any control despite vaccination and medication.

Sr no	Name and location of farm	Flock strength	Age of the flock when N.D first detected	Total no of bird died	Overhead cost per chick per day (Rs)	Cost of chick (Rs)	ND vaccination cost per chick (Rs)	Feed intake per chick till day before mortality (Rs)	Feed cost per kg (Rs)	Cost of medicine during the outbreak per chick (Rs)	Cost of other vaccination, medication and biosecurity measure per bird (Rs)	Cost of meat per kg (Rs)
1	Adarsh Poultry Farm, Navli	27676	23	3912	0.15	21	0.50	1.12	27	1.20	0.5	60
2	S.K.Poultry Farm, Vaghashi	4665	31	606	0.15	21	0.58	2.45	27	1	0.6	60
3	Jaymin Poultry Farm, Vaghashi	9508	34	1086	0.15	21	0.58	2.9	27	1	0.6	60
4	Jayambe Poultry Farm, Vera	22500	17	1800	0.15	21	0.16	0.78	27	1	0.6	60
5	Denthal Poultry Farm, Khambholaj	2800	15	1540	0.15	21	0.16	0.54	27	0.8	0.6	60
6	R.R. Poultry Farm, Napad	1000	14	800	0.15	21	0.16	0.5	27	0.5	0.3	60
7	Nasib Poultry Farm, Navli	7100	23	2950	0.15	21	0.16	1.3	27	0.6	0.5	60
8	Jalpa Poultry Farm, Utarshanda	4800	28	2880	0.15	21`	0.16	1.9	27	0.6	0.5	60
9	Tirupati Poultry Farm, Vadod	4300	29	645	0.15	21	0.16	1.9	27	0.6	0.6	60
10	Shivam Poultry Farm, Khambolaj	5300	23	755	0.15	21	0.16	1.3	27	0.6	0.5	60

Table 1: Information collected from different broiler flocks during Newcastle disease outbreaks to calculate economic losses.

- **The loss in form of vaccination for prevention of Newcastle disease:** Conventional vaccination with live and/or oil emulsion vaccines cannot assure the prevention of virus circulation**.** As evident in Table.1 ten broiler farms were vaccinated routinely and following standard vaccination protocols. The loss in the form of vaccination ranged from 103 to 1956 rupees. The overall vaccination loss was 4759 rupees and it contributed only 0.08 % out of total economic loss (Table 3).
- **Loss from reduced body weight gain:** As evident in table 2 body weight of affected broiler farms was ranged from 0.37 to 1.16 kg. Also evident in Table 3 economic loss due to reduced body weight gain was ranged from 11160 to 1179900 rupees which contribute 62.97 % out of total economic loss. The overall loss was 3635904 rupees. Major economic impacts due to Newcastle disease was in the form of reduced body weight gain in broiler farm.

Sr No	Name and location of farm	FCR	Standard FCR	Difference FCR	Day of termination of flock	Actual body weight at the termination of flock (Gram)	Standard body weight at the termination of flock (Gram)	Reduced body weight gain of affected bird (kg)
1	Adarsh Poultry Farm, Navli	2	1.7	0.3	37	1300	2090	0.79
2	S.K.Poultry Farm, Vaghashi	1.92	1.7	0.22	36	1640	2005	0.37
3	Jaymin Poultry Farm, Vaghashi	1.94	1.7	0.24	42	2001	2550	0.55
4	Jayambe Poultry Farm, Vera	2.1	1.7	0.4	42	1600	2550	0.95
5	Denthal Poultry Farm, Khambholaj	2,2	1.7	0.5	40	1500	2360	0.86
6	R.R. Poultry Farm, Napad	2	1.7	0.3	31	700	1625	0.93
7	Nasib Poultry Farm, Navli	2.2	1.7	0.5	35	1000	1925	0.93
8	Jalpa Poultry Farm, Utarshanda	2	1.7	0.3	39	1200	2265	1.1
9	Tirupati Poultry Farm, Vadod	2.3	1.7	0.6	41	1300	2455	1.16
10	Shivam Poultry Farm, Khambolaj	2.1	1.7	0.4	39	1200	2265	1.1

Table 2: Information regarding name and location of farm difference FCR and reduced body weight gain of affected bird.

- **Loss in form of treatment of affected flock**: As seen on Table 3 ten broiler farms were shown the economic loss in the form of treatment cost from 100 to 28517 rupees. The overall treatment cost was 71868 rupees in all the affected farms. Loss from treatment was contributed 1.24 % out of total economic loss.
- **Loss in form of increased FCR:** As mentioned in Table 2 difference in FCR was ranged from 0.22 to 0.6 and economic losses due to increased FCR in affected broiler flocks were ranged from 1296 to 357696 rupees (Table 3). The overall loss was 994731 rupees which contribute only 17.23 % out of total economic loss.

Sr No	Name and location of farm	Mortality loss (Rs)	Loss in form of vaccination (Rs.)	Lost due to reduced body weight (Rs)	Lost due to increased FCR (Rs)	Medication during outbreaks (Rs)	Other Vaccination, Biosecurity, & Medication cost (Rs)	Total lost (Rs)	Economic loss per bird (Rs)
1	Adarsh Poultry Farm, Navli	213947	1956	1126414	250235	28517	14258	1635327	59.09
2	S.K. Poultry Farm, Vaghashi	55630	351	90110	39541	4059	364	190055	40.74
3	Jaymin Poultry Farm, Vaghashi	113378	630	277926	109204	8922	652	510712	53.71
4	Jayambe Poultry Farm, Vera	80298	288	1179900	357696	20700	1080	1639962	72.89
5	Denthal Poultry Farm, Khambholaj	58258	246	65016	26195	1008	462	151185	53.99
6	R.R. Poultry Farm, Napad	34080	128	11160	1296	100	240	47004	47.00
7	Nasib Poultry Farm, Navli	175673	472	231570	56025	2490	1475	467705	65.87
8	Jalpa Poultry Farm, Utarshanda	220320	461	126720	18662	1152	1440	368755	76.82
9	Tirupati Poultry Farm, Vadod	49439	103	254388	76974	2193	387	383484	89.18
10	Shivam Poultry Farm, Khambolaj	44960	121	272700	58903	2727	378	379789	71.66
Total		1045983	4756	3635904	994731	71868	20736	Grand Total: 5773978	64.41
Parameter wise economic loss in %age		18.12	0.08	62.97	17.23	1.24	0.36	100	

Table 3: Economic Losses in Broiler farms.

- **Loss from other vaccination, biosecurity measure and other medication costs before Newcastle disease outbreak:** As seen in table 3 ten different broiler farms were shown an economic loss from other vaccination, biosecurity measure and another medication cost was ranged from 240 to 14258 rupees. The overall cost was 20736 rupees in all broiler farms. Losses due to these were contributed upto 0.36 % out of total economic loss.

During this study per bird economic loss was carried out by using formula = Total economic loss in farm/Initial strength of the flock. Among broiler, as seen in Table 3 per bird economic loss ranged from 40.74 to 89.18 rupees. The overall average per bird loss was 64.41 rupees. The commercial broiler industry was highly affected and the economic loss was 5773978 rupees due to Newcastle disease. As per our study, loss in form of reduced body weight gain share 62.97 % (3635904 rupees), followed by 18.12 % (1045983 rupees) due to mortality, 17.23 % (994731 rupees) due to increased FCR, 1.24 % (71868 rupees) treatment of affected flocks, 0.36 % (20736 rupees) due to other vaccination, biosecurity measure and other medication in the flock and 0.08% (4756 rupees) due to ND vaccination.

Discussion

The current findings on the economic impact of Newcastle disease outbreaks on broiler farms, when compared to previous studies, suggest that significant economic losses-despite vaccination efforts, including the use of the Genotype II virus strain-could reach up to 5.77 million rupees. According to the OIE, Newcastle disease is considered the fourth most devastating poultry disease, following highly pathogenic avian influenza, avian infectious bronchitis, and low pathogenic avian influenza [14] and all this causes huge economic losses among the poultry industry [15-17]. Kumar., *et al.* [17] reported that avian influenza was contributed 316 lakh rupees financial losses to poultry farmers in the Manipur state of India. The present study revealed that the commercial broiler industry was highly affected and suffering 5773978 rupees (5.77 million) of its economic loss due to Newcastle disease. This finding aligns with a study in India, where 13 flocks from 11-layer farms were affected by ND, resulting in economic losses of 3,719,223 rupees [10]. A study in Bangladesh, total economic losses were US$ 288.49 million per annum due to ND outbreaks [18]. The present study aligns with previous findings, which reported that NDV caused the death of 45 million broiler chickens, resulting in an economic loss of 6 billion PKR in the Punjab province of Pakistan during 2011-2012 [19]. Comparison to layer farms broiler industry highly affected with ND and leads to huge economic losses among broiler farms.

The mortality due to Newcastle disease observed in the present study is consistent with earlier research, which also reported high mortality in layer flocks [8]. In current study, economic loss due to mortality was 1045983 rupees and its contributing 18.12 % out of total loss. These findings are consistent with the results of Khorajiya., *et al.* [10] who reported a mortality loss worth 2998105 rupees among layer farms and stated that the highest economic losses due to Newcastle disease was observed in layer farms in the form of increased mortality. Antipas., *et al.* [20] observed 35 billion losses in the poultry industry with 55% mortality due to ND outbreaks in Chand. In contrast to another study, Newcastle disease causes great economic loss of mortality and morbidity, estimated at 75 million rupees per year in Nepal [21].

All the outbreaks in broiler farms were occurred due to the highly virulent nature of Genotype XIII (XIIIb) pathotype of NDV. All the commercial broiler farms were vaccinated with Genotype-II strain of the NDV vaccine. Currently available live and attenuated vaccines, including those based on Genotype-II NDV, have proven ineffective in protecting broiler farms against Genotype-XIII and resulted in outbreaks which lead to overall 4759 rupees losses in the form of vaccination. These findings are also in accordance with the results of Khorajiya., *et al.* [10] observed highly virulent nature of Genotype XIII outbreaks among layer farms and contributed to the loss in the form of vaccination was 25949 rupees. In Pakistan, despite the implementation of standard vaccination protocols and biosecurity measures Newcastle disease outbreaks reported and led to 200 million USD economic losses among commercial poultry farms between 2011 and 2013 [22]. Our findings were consistent with previous research by Siddique., *et al.* [22] who reported that outbreaks of Newcastle disease on commercial poultry farms in Pakistan between 2011 and 2013 were caused by a new genotype VII-f of the Newcastle disease virus.

The most significant economic losses among ND occur due to reduced body weight followed by mortality loss and our study was consistent with a previous study of losses due to ND, around the

Nairobi area mainly among the exotic chickens, were estimated at US$0.6 million in 1989 [23]. ND is the most devastating disease affecting village poultry and causes significant economic losses [24]. The costs associated with vaccinating and treating affected flocks further contribute to the economic burden imposed by Newcastle disease virus (NDV). Khorajiya., *et al.* [10] reported 228078.2 rupees economic losses among layer farms in India in form of other vaccination, biosecurity measure and other medication costs before the onset of Newcastle disease outbreak which was concurrent findings to the present study. It gave a clear idea that once ND outbreak occurred on a farm it led to very negative economic impact on poultry farmers throughout the lifespan of flock. Similar findings were reported earlier by Supramaniam., [25]. Newcastle disease in India led to heavy economic losses among broiler farmers and our study was consistent with a previous study of Munir., *et al.* [26] stated that heavy economic losses to commercial poultry in Southeast Asia due to Newcastle disease outbreaks. These findings emphasize the urgent need for a more robust surveillance program to reduce significant economic losses. They also highlight the importance of implementing effective, comprehensive preventive strategies to control Newcastle disease (ND) and its associated economic impact [27].

Conclusion

From the present study it was concluded that the commercial broiler farms which reported ND outbreaks had undergone routine preventive ND vaccination program. Presently used Genotype-II Lentogenic (LaSota, B1) and Mesogenic (R2B) vaccines were highly protective to genotypes prevailing in the field for many years in India. But, due to vaccine failure in the recent era as evolved new genotype (Genotype-XIII) of NDV causes huge economic losses worth 5773978 rupees (5.77 million) in India. The failure of previously effective live and inactivated vaccines to protect farms from Genotype XIII NDV is a major concern in the poultry industry. This underscores the need for comprehensive studies on the genotyping of a large number of NDV isolates to update and improve vaccine formulations. These issues directly impact the financial stability of the poultry industry, highlighting the crucial need to manage Newcastle disease in poultry flocks to avoid significant economic losses. This type of data, if generated from disparate geographical regions would be helpful to acquisition the global economic loss due to Newcastle in the poultry industry.

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Conflict of Interests

"The authors declare that they have no conflicts of interests of any kind".

Bibliography

1. Press Information Bureau (PIB). "Ministry of Fisheries". Animal Husbandry and Dairying (2023).
2. India Poultry Market Report (IPMR) (2023) by End Use (Food Services, Households), Distribution Channel (Traditional Retail Stores, Business to Business (B2B), Modern Retail Stores), and Region 2023-2028 (2023).
3. Sharma Ruchi., *et al.* "Economic losses due to Newcastle disease in layers in subtropical India". *Indian Journal of Animal Sciences* 93.5 (2023): 422-426.
4. Zhu, Wei., *et al.* "Phylogenetic and pathogenic analysis of Newcastle disease virus isolated from house sparrow (Passer domesticus) living around poultry farm in southern China". *Virus genes* 40 (2010): 231-235.
5. Miller Patti J., *et al.* "Newcastle disease: evolution of genotypes and the related diagnostic challenges". *Infection, Genetics and Evolution* 10.1 (2010): 26-35.
6. International Committee on Taxonomy of Viruses (ICTV). Virus Taxonomy: 2018b Release (2019).
7. Narayanan Madaboosi S., *et al.* "Molecular detection of Newcastle disease virus using Flinders Tehnology Associates-PCR". *Veterinarski Arhiv* 80.1 (2010): 51-60.
8. Khorajiya JH., *et al.* "Patho-epidemiological study on Genotype-XIII Newcastle disease virus infection in commercial vaccinated layer farms". *Veterinary World* 8.3 (2015): 372.
9. Khorajiya JH., *et al.* "Isolation, identification, biological characterization and patho-epidemiology of genotype-XIII Newcastle disease virus outbreak in commercial vaccinated broiler farms". *Indian Journal of Poultry Science 50.2 (2015): 132-137.*

10. Khorajiya JH., *et al.* "Economic impact of genotype-XIII Newcastle disease virus infection on commercial vaccinated layer farms in India". *International Journal of Livestock Research* 8.5 (2018): 280-288.

11. Cattoli Giovanni., *et al.* "Newcastle disease: a review of field recognition and current methods of laboratory detection". *Journal of Veterinary Diagnostic Investigation* 23.4 (2011): 637-656.

12. Susta L., *et al.* "Pathologic characterization of genotypes XIV and XVII Newcastle disease viruses and efficacy of classical vaccination on specific pathogen-free birds". *Veterinary Pathology* 52.1 (2015): 120-131.

13. Williams RB. "A compartmentalised model for the estimation of the cost of coccidiosis to the world's chicken production industry". *International Journal for Parasitology* 29.8 (1999): 1209-1229.

14. Anonymous. "World Livestock Disease Atlas: A Quantitative Analysis of Global Animal Health Data A (2006-2009)". In: The International Bank for Reconstruction and Development - The World Bank and the TAFS Forum (Ed.) Washington, DC, (2011): 221-229.

15. Fasina Folorunso Oludayo., *et al.* "The financial cost implications of the highly pathogenic notifiable avian influenza H5N1 in Nigeria". *Onderstepoort Journal of Veterinary Research* 75.1 (2008): 39-46.

16. Musa IW., *et al.* "Economic impact of recurrent outbreaks of Gumboro disease in a commercial poultry farm in Kano, Nigeria". (2012): 152-159.

17. Kumar B Ganesh., *et al.* "An assessment of economic losses due to avian flu in Manipur state". *Agricultural Economics Research Review* 21.1 (2008): 37-47.

18. Khatun M., *et al.* "Economic impact of newcastle disease on village chickens-a case of Bangladesh". *Asian Journal of Economics and Business* 1 (2018): 358-367.

19. Hussain J., *et al.* "An overview of poultry industry in Pakistan". *World's poultry science journal* 71.4 (2015): 689-700.

20. Antipas BB., *et al.* "Epidemiology of Newcastle disease and its economic impact in chad". *European Journal of Experimental Biology 2 (2012): 2286-2292.*

21. Mishra Upendra and P Spradbrow. "Present status of poultry in Nepal". *International Workshop on Newcastle Disease in Village Chickens Kuala Lumpur, Malaysia* (1991).

22. Siddique Naila., *et al.* "Sequence and phylogenetic analysis of virulent Newcastle disease virus isolates from Pakistan during 2009-2013 reveals circulation of new sub genotype". *Virology* 444.1-2 (2013): 37-40.

23. Musiime J. "The poultry industry in Kenya with particular reference to the Newcastle disease problem". *Proceedings of an International Workshop on Newcastle Disease in Village Chickens: Control with Thermostable Oral Vaccines, (Australian Centre for International Agricultural Research (ACIAR), Kuala Lumpur, Malaysia)* (1991).

24. Awan Manzoor Ahmed., *et al.* "The epidemiology of Newcastle disease in rural poultry: a review". *Avian Pathology* 23.3 (1994): 405-423.

25. Supramaniam P. "Economic importance of Newcastle disease vaccine to the village poultry industry in Malaysia". *Proceedings Second Asian/Pacific Poultry Health Conference* (1988).

26. Munir Muhammad., *et al.* "Sequencing and analysis of the complete genome of Newcastle disease virus isolated from a commercial poultry farm in 2010". *Archives of Virology* 157 (2012): 765-768.

27. Charkhkar Saeed., *et al.* "The evaluation and importance of Newcastle disease's economic loss in commercial layer poultry". *The Journal of Poultry Sciences and Avian Diseases* 2.1 (2024): 1-4.