



# Review of Poultry Production and Poultry Vaccine Manufacture in Nepal

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## ABSTRACT

Poultry industry is one of the strong pillars of Nepal's agricultural production system, contributing approximately 4% in the national gross domestic product. Nepal has observed commendable growth in poultry production in the past decades, but it still depends on import of feed ingredients and pharmaceuticals, including vaccines. The poultry sector provides employment and has become a major source of income to people in rural and semi-urban areas. Different viral, bacterial, protozoal and fungal diseases, including influenza, fowl typhoid, coccidiosis and mycotoxicosis, cause significant economic loss to the poultry sector of Nepal each year. Vaccines can be an effective preventive measure against poultry diseases. Nepal government together with the private sectors have initiated the production of vaccines against different poultry diseases. Nevertheless, poultry vaccine production within the country is insufficient and the vaccine demand is largely met with imports from other countries. Considering the continuous growth in the poultry production and constant threat of disease outbreaks, Government of Nepal as well as private sectors should invest more on vaccine production within the country. This article discusses the current status of poultry production and vaccine development in Nepal.

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## 1. Introduction

Poultry industry is one of the fastest growing agriculture industries in the world. Over the last few decades, poultry industry has undergone tremendous adjustments, leading to the continuous growth of this sector (Gerber, Opio, & Steinfeld, 2007). According to the Food and Agriculture Organization (FAO) statistics, global poultry population in the year 2016 was more than 23 billion which was 5 times higher than the poultry population 50 years ago (Mottet & Tempio, 2017). Human population growth, rapid urbanization, and increase in purchasing capacity of the individuals are the factors driving the increased demand for poultry products (Mottet & Tempio, 2017). Poultry meat productivity is expected to increase with more than 2.5% per annum from 1999/01 to 2030 and by 1.5% per annum from 2030 to 2050, whereas demand is expected to increase by 2.6% and 1.5%, respectively, during the same time period (FAO, 2006). In accordance, world poultry meat production soared from 9 to 122 million tonnes between the years 1961 and 2017 while egg production increased from 15 to 87 million tonnes (FAO, 2020a). The consumption of poultry products has tremendously increased in the last

three decades and the poultry market is likely to keep growing in the future as well (OECD-FAO, 2011).

Foods from the animal source are highly beneficial for all age groups for nutrition and good health, as they are rich in vitamins and micronutrients (Murphy & Allen, 2003). Poultry meat, both muscle and organ meat, and eggs are one of the best sources to supply valuable dietary proteins, vital vitamins, and minerals. Poultry products are rich in bioavailable nutrients, contain low fat and cholesterol, and are available at a cheaper price compared to the red meat (Arihara, 2006; Petracci, Bianchi, Mudalal, & Cavani, 2013). Highly bioavailable nutrients supplied through poultry products are more important particularly for infants and young children with limited gastric volume for proper physical and mental development; pregnant and lactating women who have increased nutrient requirement for fetal development and to reduce mortality among children and young infants; elderly people who have decreased intestinal absorption capacity; and also for ill and sick people for speedy recovery (Farrell, 2013; Olaoye, 2011). In this review, we have summarized the current status of poultry production, disease burden, and poultry vaccine production in Nepal.

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## 2. Contribution of Poultry Industry in the National Economy

In Nepal, two-thirds of its population residing within the country are directly or indirectly engaged in agriculture (FAO, 2020b). Livestock farming is an important aspect of agricultural business in Nepal which has been continuously growing in the past decade (Poudel, Dahal, Upadhyaya, Chaudhari, & Dhakal, 2020). Agriculture sector has 27.1% contribution in the national gross domestic product (GDP) of Nepal while the poultry subsector alone has estimated 4% contribution in GDP (FAO, 2014a; MoALD, 2020). Poultry industry has created direct and indirect employment opportunities for more than 150,000 people (Table 1). Investment in the poultry sector is about Rs. 115 billion (around US \$1.1 billion), and the investment is likely to increase further in the coming decade leading to the growth of this sector and greater contribution towards national economy (Table 1). Backyard poultry plays a pivotal role in the rural socioeconomic system as majority households in rural villages raise poultry as a source of cash income (Spradbrow, 1992). Small scale poultry farming is popular in rural and peri-urban areas of Nepal as it involves small capital investment, can be managed by women and younger children, requires smaller areas, serves as the protein source for the family, and provides extra income which can be invested in other household requirements (Acharya & Kaphle, 2015). According to the commercial poultry survey carried out in 2014-2015 in Nepal, the overall transaction in poultry sector was Rs. 33.72 billion (US \$0.33 billion) where broiler meat had highest transaction of about Rs. 20.52 billion (60.9%, US \$0.2 billion), followed by eggs, Rs. 9.13 billion (27.1%, US \$90 million); chicks, Rs.3.61 billion (10.7%, US \$30 million); and poultry manure, Rs.453.72 million (1.3%, US \$4.53 million) (CBS, 2016). Poultry manure is used not only for agriculture crops and vegetables but also as the feed for fish in the integrated fish-poultry farming system where poultry are raised on top of the pond as part of the integrated system popular in Asian countries (FAO, 2014b). Chitwan district, in Bagmati Province, can be considered as the poultry capital of Nepal as it holds highest number of poultry farms, population, and productivity (Table 1). Nepal has no long history of poultry export but recently has started export of broiler meat and eggs to Bhutan. Rapid development in the poultry industry makes Nepal self-reliant in production of meat and eggs within the country (CBS, 2016). At present, both the investment and market and supply chain of poultry have drastically increased which ensure the availability of poultry meat and eggs in every local market of Nepal (CBS, 2016). On 25th March 2021, Nepal announced itself self-sufficient in egg and meat production and progresses towards self-sufficiency in milk as well (Prasain, 2021).

## 3. Poultry Population and Productivity in Nepal

According to the Ministry of Agriculture and Livestock Development (MoALD) of Nepal, in 2017-2018, there were more than 72 million fowls, 400,000 ducks, 12 million laying hens, and 186,000 laying ducks in Nepal (Figure 1). The population of chicken increased by more than 195% within a decade with average annual growth rate of around 19.5% while that of the ducks was around 5.62% with annual growth of 0.56% (Poudel et al., 2020). Along with the commercial poultry, rearing of indigenous Nepalese poultry breeds was also increased in the rural and village areas of Nepal. These local breeds are hardy in nature and adapt to the harsh environment and are resistant to many pathogens (FAO, 2014a).

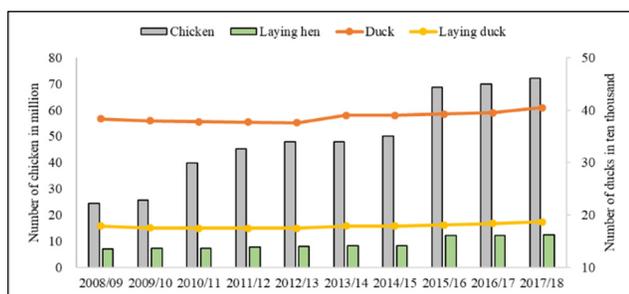
Exotic breeds, compared to the local breeds, are mostly reared under intensive management systems with adequate housing, nutrition, and health control. The exotic breeds commercially popular in Nepal include Cobb

**Table 1. Current status of poultry industry in Nepal (CBS, 2016; FAO, 2014a; Singh, 2018; MoALD, 2020).**

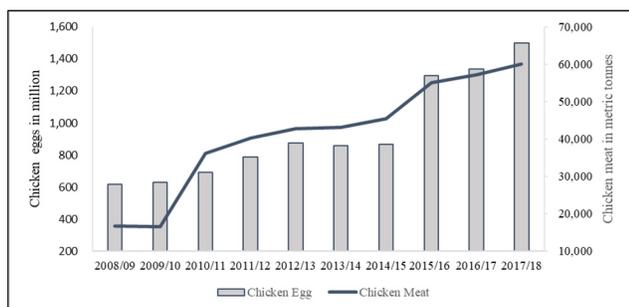
Poultry scenario	Number
GDP contribution by agriculture	27.1%
GDP contribution by poultry	4%
AGDP contribution by poultry	8%
Investment in poultry sector	Rs. 115 billion (around US \$ 1.1 billion)
Import	1,091,730 (985,503 broiler and 107,894-layer parent stock in 2011/2012)
Export	No history of export but recently started to export broilers and eggs to Bhutan
Contribution in total meat yield	17.4%
World ranking in chicken meat production	112
World ranking in egg production	92
Feed industries	111
Registered poultry farm	16,000
Hatcheries (2018-2019)	320
Medicine dealers and sub-dealers	2,800
Meat processors	9
Egg tray and cartoon industries	16
Per capita chicken meat consumption	5.7
Per capita chicken egg consumption	61
Broiler chicken	65 million
Layers chicken	12 million
Total egg production per day	2.9 million
Egg production per bird	280-300
Total meat production per day	350 tons
Overall growth in poultry	2.04 % per year
Broiler farm (2014-2015)	
Up to 1000	6,144
1001-5000	12,036
5001-10,000	1,818
>10,000	472
Layers farm (2014-2015)	
Up to 1000	426
1001-5000	692
5001-10,000	168
>10,000	131
Employees	150,000 directly and many more indirectly
Broiler production	2.5 million per week
Layers production	118,208 per week
Koilers production	250,000 per week
New sectors in poultry industry	Ostrich, Turkey, and Quail
Feed production	3,000 MT per day
Annual feed industry growth	8-10%
Large scale pellet feed industry	46
Investment in feed industry	Rs. 40 billion (US \$0.4 billion)
Feed type	Mash feed and pellet feed
District with highest number of poultry farms (2014-2015)	Chitwan (1,920)
District with highest broiler production (2014-2015)	Chitwan (5.3 million; 10%)
District with highest egg production (2014-2015)	Chitwan (0.8 billion; 68%)

100, Cobb 500, Venn Cobb, Cobb Avian, Lohman Indian River, Hubbard Flex, Dominant CZ, Kasila, Bovans brown, B.V. 380, Hyline brown, Lohman brown, H&N Nick brown, Hisex and Isa brown (FAO, 2014a).

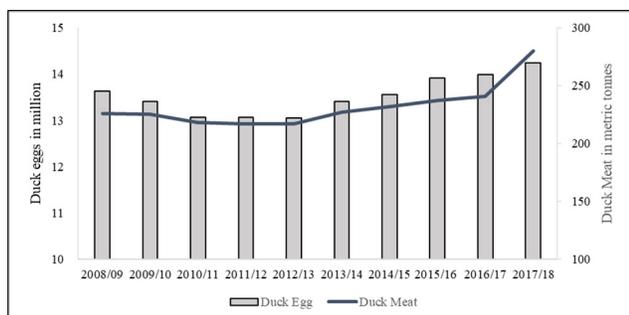
Nepal is ranked 112th in meat production and 92nd in poultry egg production in the world (FAO, 2014a; Singh, 2018). There are more than 1,400 commercial layer farms and more than 20,000 commercial broiler farms in Nepal (Table-1). Poultry sector has supplied about 17.4% of total animal protein in Nepal. Chickens have contributed more than 99% of total poultry meat supply while ducks contributed the rest (Figures 2-3). Likewise, chickens contributed about 99.2% (1.49 billion) of total egg production of the country and ducks did the remaining (14.24 million). Per capita Nepalese population consumes 5.7 kg chicken meat and 3.66 kg (i.e., around 61) eggs annually which is far below the global average per capita consumption of 14.1 kg meat and 8.9 kg eggs (Mottet & Tempio, 2017; Singh, 2018). This data indicates the need for increasing poultry productivity at cheaper price to address this consumption gap (CBS, 2016).



**Figure 1. Trend of poultry population in Nepal (2008/09 – 2017/18) (MoALD, 2020).**



**Figure 2. Trend of chicken meat and egg production in Nepal (2008/09 – 2017/18) (MoALD, 2020).**



**Figure 3. Trend of duck meat and eggs production in Nepal (2008/09 – 2017/18) (MoALD, 2020).**

#### 4. Challenges Faced by the Poultry Industry in Nepal

Though the number of birds and productivity is increasing, poultry sector in Nepal faces many challenges. First and foremost, the cost of per unit production of poultry is high due to costly raw feed materials and inefficient marketing structure (Dhakal, Joshi, Karn, Bhusal, & Acharya, 2019). More than 75% cost of production is attributed to feed and treatments (Sharma, 2010). Nepal is heavily reliant on poultry feed ingredients, especially for maize as the energy source and soybean, sunflower, and meat and bone meals (MBM) as protein sources. Around 0.55 million tonnes of maize are utilized for poultry feed per annum of which only 35% is domestic production. Almost 99% of protein sources are imported including around 180,000 tonnes of soybean meal, and around 27,000 tonnes of sunflower and MBM per year. On average Rs. 1.8 billion per year is invested to import poultry feed supplement (Singh, 2018). Lower optimum productivity of eggs and higher mortality of birds due to periodic outbreak of various infectious diseases add another layer of challenges in poultry industry (Osti, Bhattarai, Chaudhary, & Singh, 2017). Poor biosecurity measures, unavailability of well-equipped disease diagnosis facilities, lack of well-trained technical manpower, and inappropriate use of antibiotics leading to antibiotic resistance constitute other major problems of poultry farming in Nepal (Acharya & Kaphle, 2015). Lack of proper regulatory mechanisms for fixing market price based on production cost results in a highly fluctuating market value of chicken eggs and meats which can lead to huge economic burden among farmers (Acharya & Kaphle, 2015). The lower production cost of poultry in India, open border, and lack of enforceable regulations and quarantine facilities lead to smuggling of poultry and poultry products in Nepal. This illegal import results in unhealthy competition with the in-country production system while raising the risk of transmission of various poultry pathogens. The porous border with neighboring country, weak epidemiological investigations, poor monitoring and quarantine, and unavailability of efficient drugs and vaccines are primarily responsible for endemicity of many poultry-related bacterial, viral and parasitic diseases in Nepal (Acharya & Kaphle, 2015; Dhakal et al., 2019).

There were number of outbreaks of the nine World Organization for Animal Health (OIE)-listed poultry diseases in Nepal, reported from both the commercial and backyard poultry enterprises (VEC, 2018). The outbreaks of coccidiosis, fowl pox, infectious bursal disease (IBD) and Newcastle disease (ND) were more frequent than other diseases (Table 2). Maximum death was caused by IBD (36.68%), followed by coccidiosis (23.99%) and ND (18.51%). Besides these OIE-listed pathogens, several other pathogens also impact the poultry industry in Nepal. While studying the case flow of Central Veterinary Laboratory (CVL), Kathmandu, Nepal for a period of one year, Gompo et al. (2019) observed that there were 2,271 total poultry cases registered where colibacillosis (26%), mycotoxicity (13%), ascites (10%), chronic respiratory disease (CRD, 9%), IBD (7%), ND (7%), avian influenza (1%), and coccidiosis (1%) contributed mainly while remaining 21% cases were non-specified. Colibacillosis, caused by *Escherichia coli*, is the most common cause of bacterial infection in poultry farms in Nepal which is associated with poor farm hygiene (CVL, 2015; Gautam, Devekota, & Thapaliya,, 2017; Shrestha & Shrestha, 2020). Mycotoxicosis is another leading poultry disease caused by ingestion of fungal aflatoxin B1 and B2 having higher incidence in the pre-monsoon and monsoon seasons (Ae et al., 2007; Aryal & Karki, 2009; Gompo et al., 2019). The incidence of ascites is also higher, and the maximum occurrence is observed in winter season since the farmer try to keep their poultry warm in poorly ventilated housing system and thus the low oxygen availability

leads to the development of ascites (Gompo et al., 2019; Gupta, 2011; Shrestha & Shrestha, 2020). In summer and winter months, poultry are mainly infected by CRD (Rajkumar, Reddy, & Tech, 2017). Besides the economic loss in the poultry sector, certain poultry pathogens including avian influenza virus, Salmonella and Escherichia coli, also possess the risk

of transmission to humans (Dale & Brown, 2013). In March 2019, first human death due to avian influenza A virus subtype H5N1 was reported from Nepal (Shrestha, 2019).

**Table 2. World Organization for Animal Health (OIE)-listed poultry disease outbreaks in Nepal in 2018 (VEC, 2018).**

Disease Name	Outbreak	Susceptible	Affected	Dead
Coccidiosis	583	48.62%	68272	5.54%
Fowl pox	252	21.01%	11332	0.92%
Infectious bursal disease	116	9.67%	183567	14.91%
Newcastle disease	90	7.50%	901866	73.27%
Fowl typhoid	55	4.58%	1616	0.13%
Pullorum disease	43	3.58%	4789	0.38%
Fowl cholera	30	2.50%	2088	0.16%
Avian infectious bronchitis	27	2.25%	32030	2.60%
Highly pathogenic avian influenza	3	0.25%	25254	2.05%

## 5. Poultry Related Policies and Gaps

Poultry is the leading industry of Nepal and has tremendous capability to boost the country's economy. However, the national policies need to be updated to bridge the developmental gaps. Animal Health and Livestock Service Act 2055 (1999 AD) prioritizes to systematize and develop the animal husbandry business and to provide necessary arrangement related to healthy production, sale, distribution, export and import of animal products or animal production inputs. However, there is still no proper implementation and regulation of Poultry Policy 2068 (2011 AD) and Animal Slaughterhouse and Meat Inspection Act 2055 (1999 AD). Bird Flu Control Order, 2064 (2007 AD), which is specifically aimed to control bird flu in the country by providing the compensation to the farmer is in place. In addition, Government of Nepal provides 75% premium of insurance and only 25% premium cost is paid by the farmer for livestock and poultry insurance (DLS, 2021). There is still lack of common interest or knowhow in different poultry related unions, federations, associations, and institutions for the development of poultry sector, specially making it self-reliant on raw materials and therapeutics. Government of Nepal should formulate integrated national livestock and poultry policy to cope with current changing national and international environments that can sustainably increase diversification, commercialization, and competitiveness of the poultry sector (Pradhanang et al., 2015).

## 6. Poultry Vaccine Production in Nepal

Vaccines for veterinary use include inactivated/killed vaccines; live-attenuated vaccines; toxoids; recombinant subunit vaccines; RNA/DNA-based vaccines; and vectored-vaccines (McVey & Shi, 2010). Livestock vaccine production in Nepal began in 1960s while the poultry vaccine production was started from 1968 (Poudel et al., 2020). At first, ND F1 strain, ND R2B strain and fowl pox vaccines were produced in Nepal (Gautam, Ghimire, Shrestha, & Gautam, 2018). The severe outbreak of IBD in 1996 demanded for the production of IBD vaccine and hence its production was started in 1998 (Poudel et al., 2020). ND Lasota strain vaccine production was also started in 1998 to protect birds from velogenic

strain of ND and this vaccine was well accepted as it was delivered through the drinking water. Traditionally, poultry vaccines in Nepal used to be produced in fertile eggs available at local hatcheries. Since 1997, specific pathogen free (SPF) eggs have been used to produce poultry vaccines which was initiated with the financial support from Strengthening Veterinary Service for Livestock Disease Control (SVSLDC) project (Gautam et al., 2018). The heat stable vaccine against ND, i.e. ND12, was produced in 2008 targeting the backyard poultry (Gautam et al., 2018; NVPL, 2019; NVPL, 2020).

At present, three different laboratories have been registered for poultry vaccine production in Nepal (Table 3) (Biovac, 2020; Hester, 2020). National Vaccine Production Laboratory (NVPL) is the government owned laboratory while Hester Biosciences Nepal and Biovac Nepal are private laboratories (Poudel et al., 2020). In recent years, private companies also have started production of vaccines in Nepal, but the production quantity and market share are not clear. The maximum supply of in-country produced vaccine so far is carried out by NVPL. As per NVPL's annual report (2018-2019), ND F1 strain; fowl pox and IBD; ND R2B and Lasota; and ND-I2 vaccine doses produced in the year 2018 were 15, 8, 5, and 1.96 million, respectively (Poudel et al., 2020).

Vaccines of many poultry diseases are not manufactured in Nepal and hence they are imported from foreign countries. In the year 2014-2015, 549 million doses of poultry vaccines were imported from foreign countries which increased by >300% in 2018-2019 as Nepal imported 2,378 million doses of poultry vaccines in that year (Figure 4) (Poudel et al., 2020). Vaccines imported from other countries may not necessarily provide protection against field strain of pathogens circulating in Nepal. Lack of proper cold chain maintenance during transportation might also play role in variable vaccine effectiveness. Moreover, there are not enough studies determining the field performance of various poultry vaccines in Nepal. These facts highlight the need for identifying the various circulating pathogens within the country, developing vaccines targeting the circulating strains of pathogens, and performing vaccine efficacy studies periodically.

## 7. Economic Aspects and Distribution of Poultry Vaccines

Cost of feed, chicks, medicines, and vaccines are the major expenses in the poultry industry of Nepal (CBS, 2016). On average, 62.3% of the

poultry farmers in Nepal depend on loan out of which 45% need loans for housing, 30% for buying chicks, 19.9% for feed, 2.3% for vaccine, and 1% for machinery (CBS, 2016). The cost of vaccine also plays significant role in the farmers economy and return on investment. Large commercial farms import different types of vaccines from other countries regardless of the cost of vaccines which increases the cost of poultry production. At the same time, small-scale farmers do not have access to such vaccines leaving their birds at risk of infection. Thus, there is a need for producing different types of poultry vaccines within the country and make them available at lower price to all poultry farmers. NVPL supplies quality and effective vaccines against certain diseases (Table 3) in nominal price to the farmers. Before 1989, NVPL used to distribute vaccines free of cost to the farmers but after 1989 it started to charge certain nominal price (NVPL, 2020). These vaccines are either supplied at low cost through the stockiest or provided free of cost through National Animal Disease Control Program (NADCP). NVPL should increase the types and quantity of vaccines which will be easily accessible and affordable to farmers.

**Table 3. Poultry vaccines manufactured in Nepal (Biovac, 2020; Hester, 2020; NVPL, 2019).**

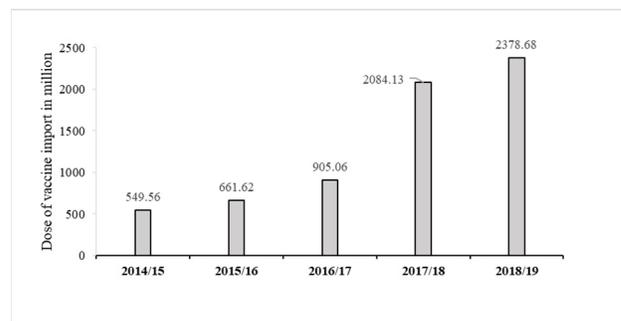
Manufacturer	Disease	Type	Vaccine
Biovac Nepal Private Limited	Newcastle disease	Live	ND I-2 vaccine
Hester Biosciences Nepal Private Limited	Newcastle disease	Live	Newcastle disease LaSota strain vaccine
	IBD	Live	Infectious bursal disease Winterfield 2512 strain vaccine
	Fowl typhoid	Live	Fowl typhoid Salmonella gallinarum 9R strain vaccine
	IB	Live	Avian infectious bronchitis 4/91 type strain vaccine
	Marek's disease	Live	Marek's disease frozen rispens strain vaccine
	Hydropericardium	Inactivated	Inclusion body hepatitis adenovirus type 4 strain vaccine
National Vaccine Production Laboratory	Newcastle disease	Live	Newcastle disease F1 strain vaccine
	Newcastle disease	Live	Newcastle disease LaSota strain vaccine
	Newcastle disease	Live	Newcastle disease I-2 strain vaccine
	Newcastle disease	Live	Newcastle disease R2B strain vaccine
	Fowl pox	Live	Fowl pox vaccine
	IBD	Live	IBD intermediate strain vaccine

### 8. Poultry Vaccines to Reduce Use of Antibiotics

Use of antibiotics in the poultry sector during the past 50 years has helped the growth of the industry by preventing negative impact of various bacterial diseases (Mehdi et al., 2018). In Nepal, most of the poultry production is done in intensive farming system (CBS, 2016; FAO, 2014a). Government of Nepal has released National Antibiotics Treatment

Guidelines in 2014 to address the issues of antimicrobial resistance and commenced policies for no antibiotics in feed supplements. Antibiotics were used as a growth promoter in animal feed, but recently MoALD has banned the use of antibiotic feed supplement as a growth promoter in feed; however, there are no alternatives of antibiotics for the prevention and treatment of animal diseases except some use of prebiotics, probiotics, and photoactive molecules. Top seven antibiotics used in veterinary sector in Nepal are tetracycline, enrofloxacin, neomycin, doxycycline, levofloxacin, colistin and tylosin and the most inappropriately prescribed antibiotics are ampicillin, amoxicillin, ceftriaxone and gentamicin (Acharya & Wilson, 2019). Many poultry farmers in villages give self-medication of antibiotics and the indiscriminate use of antibiotics without proper drug sensitivity testing leads to the development of antibiotic resistance in the bacteria. The supply of poultry meat and eggs in the market without proper withdrawal period leads to the presence of antibiotic residues. Antibiotic residues present in the manure used for agricultural crops eventually reaches to humans as end consumer of agricultural products through biomagnification. Effective use of vaccines can prevent poultry infections from different pathogens as well as delay the resistance development in pathogens against these antibiotics (Marangon & Busani, 2006). Therefore, development and use of vaccines against different bacterial pathogens of poultry can also contribute towards the reduction of antibiotic resistance problem in poultry sector protecting poultry as well as human health.

**Figure 4. Import of poultry vaccines in Nepal from 2014/15 – 2018/19**



(VSDRL, 2020).

### 9. Poultry Vaccine Production Issues in Nepal

Though various poultry vaccines are being used continuously in Nepal, data are lacking regarding their immunogenicity and efficacy in the field. Vaccines should match with field strains of viruses, bacteria, or parasites to be efficacious and if not, they need to be upgraded. However, mechanisms to continuously monitor field strains of viruses, bacteria, and parasites in poultry are lacking in Nepal. This becomes even more important with imported vaccines as they may not necessarily provide cross-reactive immunity and cross-protective mechanisms against pathogens that are specifically adapted to microclimatic conditions of Nepal. Lack of resources, e.g., the specific pathogen free (SPF) eggs and animal experimental units, limit the proper testing and evaluation of these vaccines before their commercial use. With increased poultry production, it is apparent that the demand for poultry vaccines will also increase. Therefore, the Government of Nepal should scale up its existing poultry vaccine production capabilities. For this, human resource capacity building and use of latest updated technologies should be considered. A strong research

mechanism should be established to continuously monitor the pathogen diversity and evolution within the country and to evaluate field efficacy of in-country produced or imported vaccines.

## 10. Conclusion

Poultry industry is one of the booming industries in Nepal. Investment in poultry industry in the past decade has significantly contributed to the national economy and has created employment opportunities for significant population. As a result of the ongoing pandemic of coronavirus disease (COVID-19), many Nepali citizens are returning home after losing their foreign employments. It is highly likely that agriculture and more specifically poultry farming will be one of the major attractions to them. Hence, poultry population and production are likely to increase in coming years. Outbreaks of various poultry diseases frequently suggest the need for regular monitoring and surveillance of poultry diseases and development of effective vaccines against them. Despite the continuous efforts from NVPL, poultry vaccines being produced within the country are not adequate and millions of doses of vaccines are being imported each year. Imported vaccines may not efficiently work as they may not match with the prevailing strains or subtypes of pathogens within the country. Hence, better understanding of the behavior and ecology of prevailing pathogens within the country is necessary. Changing pathogen characteristics may demand for changes in vaccine formulations. Research work should be improved in Nepal to quantify whether the existing vaccines, either manufactured within the country or imported, are working efficiently. More investment from both governmental and non-governmental sectors is necessary for research and development of novel adjuvants and improved vaccine formulations. Regular monitoring and supervision of vaccine production system, cold chain maintenance, and safety and quality standards should be done to reduce chances of vaccine failures. Government and private sectors should work together to make Nepal self-reliant in poultry vaccine production.

## References

- Acharya, K. P., & Kaphle, K. (2015). Major Issues for Sustainable Poultry Sector in Nepal: A REVIEW. *Global Journal of Animal Scientific Research*, 3(1), 227–239. Retrieved January 23, 2021, from <http://archives.gjasr.com/index.php/GJASR/article/view/149>
- Acharya, K. P., & Wilson, R. T. (2019). Antimicrobial Resistance in Nepal. *Frontiers in Medicine*, 6, 1–10. <https://doi.org/10.3389/fmed.2019.00105>
- Ae, Z. J., Wilson, J. P., David, A. E., Ae, M. W., Casper, H. H., Jurjevic, Z., ... Casper, H. H. (2007). Changes in fungi and mycotoxins in pearl millet under controlled storage conditions. *Springer*, 164(5), 229–239. <https://doi.org/10.1007/s11046-007-9042-7>
- Arihara, K. (2006). Strategies for designing novel functional meat products. *Meat Science*, 74, 219–229. <https://doi.org/10.1016/j.meatsci.2006.04.028>
- Aryal, S. R., & Karki, D. (2009). Prevalence of aflatoxin B1 and B2 in poultry feed. *Nepal Agriculture Research Journal*, 9, 192–195. Retrieved from <http://narc.gov.np/publicaton/pdf>
- Biovac. (2020). Vaccine Research, Development and Production. Retrieved April 10, 2021, from <https://biovacnepal.com/>
- CBS. (2016). Summary Report & Major Findings Nepal Commercial Poultry Survey 2071/72. Thapathali, kathmandu, Nepal. Retrieved from <https://www.scribd.com/document/347608850/Nepal-Commercial-Poultry-Survey-2071-72>
- CVL. (2015). Annual Technical Report 2014/15. Retrieved May 10, 2020, from <http://www.cvl.gov.np/uploads/files/5324820354.pdf>
- Dale, E., & Brown, C. (2013). Zoonotic diseases from poultry. *Brazilian Journal of Veterinary Pathology*, 6(2), 76–82.
- Dhakal, R., Joshi, B., Karn, R., Bhusal, S., & Acharya, B. (2019). A Review on Scenario, Challenges and Prospects of Poultry Production in Nepal. *Malaysian Journal of Sustainable Agriculture*, (November), 60–63. <https://doi.org/10.26480/mjsa.02.2019.60.63>
- DLS. (2021). Department of Livestock Services, Act and Policies. Retrieved February 13, 2021, from <http://www.dls.gov.np/downloadsdetail/4/2018/41339141>
- FAO. (2006). World agriculture: towards 2030/2050 Prospects for food, nutrition, agriculture and major commodity groups. FAO, (June), 78.
- FAO. (2014a). Poultry Sector Nepal. In FAO Animal Production and Health Livestock Country Reviews. No. 8. 4-16.
- FAO. (2014b). Decision tools for family poultry development. FAO Animal Production and Health Guidelines No. 16, FAO., Rome, Italy. Retrieved May 10, 2020, from <http://www.fao.org/3/a-i3542e.pdf>
- FAO. (2020a). Gateway to poultry production and products. Retrieved May 7, 2020, from <http://www.fao.org/poultry-production-products/production/en/>
- FAO. (2020b). Nepal at a glance, FAO in Nepal. Retrieved May 9, 2020, from <http://www.fao.org/nepal/fao-in-nepal/nepal-at-a-glance/en/>
- Farrell, D. (2013). The role of poultry in human nutrition. FAO, 1-3. Retrieved May 10, 2020, from <http://www.fao.org/3/al709e/al709e00.pdf>
- Gautam, G., Devkota, B., & Thapaliya, S. (2017). Recent Case Flow Pattern in Veterinary Teaching Hospital of Agriculture And Forestry University, Chitwan, Nepal. *Journal of Agriculture and Forestry University*, 1, 119–128.
- Gautam, S. P., Ghimire, N. P., Shrestha, S., & Gautam, S. (2018). History of Vaccine Production and Vaccination in Nepal. *Golden Jubilee Souvenir*, 1(1), 136–143.
- Gerber, P., Opio, C., & Steinfeld, H. (2007). Poultry production and the environment-A review. FAO, 1–27. Retrieved from [http://www.fao.org/ag/againfo/home/events/bangkok2007/docs/part2/2\\_2.pdf](http://www.fao.org/ag/againfo/home/events/bangkok2007/docs/part2/2_2.pdf)
- Gompo, T. R., Pokhrel, U., Shah, B. R., & Bhatta, D. D. (2019). Epidemiology of Important Poultry Diseases in Nepal. *Nepalese Veterinary Journal*, 36, 8–14. <https://doi.org/10.3126/nvj.v36i0.27746>
- Gupta, A. R. (2011). Ascites syndrome in poultry: a review. *Worlds Poultry Science Journal*, 67(3), 457–468.
- Hester. (2020). POULTRY LIVE VACCINES AND HEALTH PRODUCTS. Retrieved May 11, 2020, from <https://www.hester.com.np/poultry-products>
- Marangon, S., & Busani, L. (2006). The use of vaccination in poultry production. In *Rev. sci. tech. Off. int. Epiz* (Vol. 26), 265-274. Retrieved from <https://www.oie.int/doc/ged/D4243.PDF>
- McVey, S., & Shi, J. (2010). Vaccines in Veterinary Medicine: A Brief Review of History and Technology. *Veterinary Clinics of North America - Small Animal Practice*, Vol. 25, pp. 219–232. <https://doi.org/10.1016/j.cvsm.2010.02.001>
- Mehdi, Y., Létourneau-Montminy, M. P., Gaucher, M. Lou, Chorfi, Y., Suresh, G., Rouissi, T., ... Godbout, S. (2018). Use of antibiotics in broiler production: Global impacts and alternatives. *Animal Nutrition*, Vol. 4, pp. 170–178. <https://doi.org/10.1016/j.aninu.2018.03.002>
- MoALD. (2020). Nepal Agriculture Statistics 2017/18. Retrieved May 9, 2020, from [https://www.moald.gov.np/publication/Agriculture Statistics](https://www.moald.gov.np/publication/Agriculture%20Statistics)
- Mottet, A., & Tempio, G. (2017). Global poultry production: Current state and future outlook and challenges. *World's Poultry Science Journal*, 73(2), 245–256. <https://doi.org/10.1017/S0043933917000071>
- Murphy, S. P., & Allen, L. H. (2003). Animal Source Foods to Improve Micronutrient Nutrition and Human Function in Developing Countries. *J. Nutr*, 133(February), 3932–3935.
- NVPL. (2019). Annual Report 2075/76. National Vaccine Production Laboratory, Tripureshwor, Kathmandu. 1, 45.
- NVPL. (2020). Vaccine and Production Year. Retrieved May 10, 2020, from <http://nvpl.gov.np/>

- OECD-FAO. (2011). OECD-FAO Agricultural Outlook 2011-2020. Retrieved July 23, 2020, from <https://thepoultrysite.com/articles/ocedfao-agricultural-outlook-20112020>
- Olaoye, O. A. (2011). Meat: An overview of its composition, biochemical changes and associated microbial agents. *International Food Research Journal*, 18(3), 877–885.
- Osti, R., Bhattarai, D., Chaudhary, H., & Singh, V. (2017). Poultry Production in Nepal: Characteristics, Productivity and Constraints. *International Journal of Applied Sciences and Biotechnology*, 5(2), 222–226. <https://doi.org/10.3126/ijasbt.v5i2.17616>
- Petracci, M., Bianchi, M., Mudalal, S., & Cavani, C. (2013). Functional ingredients for poultry meat products. *Trends in Food Science and Technology*, 33(1), 27–39. <https://doi.org/10.1016/j.tifs.2013.06.004>
- Poudel, U., Dahal, U., Upadhyaya, N., Chaudhari, S., & Dhakal, S. (2020). Livestock and Poultry Production in Nepal and Current Status of Vaccine Development. *Vaccines*, 8(2), 322. <https://doi.org/10.3390/vaccines8020322>
- Pradhanang, U., Pradhanang, S., Sthapit, A., Krakauer, N., Jha, A., & Lakhankar, T. (2015). National Livestock Policy of Nepal: Needs and Opportunities. *Agriculture*, 5(1), 103–131. <https://doi.org/10.3390/agriculture5010103>
- Prasain, S. (2021, March 25). Nepal becomes self-sufficient in egg and meat production. *The Kathmandu Post*. Retrieved April 10, 2021 from <https://kathmandupost.com/money/2021/03/25/nepal-becomes-self-sufficient-in-egg-and-meat-production>
- Rajkumar, S., Reddy, M., & Tech, R. S. (2017). Incidence and risk factors of chronic respiratory disease in Indian poultry flocks. *International Journal of Science, Environment and Technology*, 6(1), 662–668. Retrieved from <http://www.ijset.net/journal/1590.pdf>
- Sharma, B. (2010). Poultry Production, Management and Bio-Security Measures. *Journal of Agriculture and Environment*, 11, 120–125. <https://doi.org/10.3126/aej.v11i0.3659>
- Shrestha, A. (2019, May 3). First bird flu death reported in Nepal. *The Himalayan Times*. Retrieved May 10, 2020, from <https://thehimalayantimes.com/nepal/first-bird-flu-death-reported-in-nepal/>
- Shrestha, S., & Shrestha, B. K. (2020). CASE-FLOW ANALYSIS OF NATIONAL AVIAN DISEASE INVESTIGATION LABORATORY (NADIL), CHITWAN DURING AUGUST 2016 TO JANUARY 2017. Retrieved May 10, 2020, from <https://www.farm.com.np/research/poultry-disease-in-nepal/>
- Singh, S. (2018). Overview of Nepalese Poultry Industry. Retrieved January 23, 2021, from [http://www.vcn.gov.np/uploads/files/Overview\\_of\\_Nepalese\\_Poultry\\_Industry\\_Dr\\_Subir.pdf](http://www.vcn.gov.np/uploads/files/Overview_of_Nepalese_Poultry_Industry_Dr_Subir.pdf)
- Spradbrow, P. (1992). Newcastle Disease in Village Chickens Control with Thermostable Oral Vaccines. *Proceedings of an International Workshop Held in Kuala Lumpur, Malaysia, 6-10 October 1991*, (39), 189.
- VEC. (2018). National Annual Disease Report. Annual epidemiological bulletin January-December 2018. Animal disease investigation and control division, Tripureshwor, Kathmandu, Nepal. 14, 38.
- VSDRL. (2020). Annual Progress and Technical Report-2018/19. Retrieved January 24, 2021, from <http://www.vsdrl.gov.np/downloadsdetail/3/2018/44178961>