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Vaccination and Poultry Production

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ABSTRACT

This review aims to provide information regarding the use of vaccines and the methods of vaccination in the poultry industry. Due to genetic selection for fast growth, large breast muscle and egg production, modern day poultry species especially domesticated chickens have lost some of their ancestor's immune ability or defence mechanism making them prone to diseases. Also, environmental changes due to climate change has boost the rapid emergence and the spread of poultry disease making the immune defense system of poultry species incapable of protecting the birds from infections and sudden death. The widespread and distribution of Newcastle disease (ND) and some zoonotic diseases such as Avian Influenza (AI) caused a detrimental effect on the poultry sector and on the human population as well. To boost the immune system of poultry birds to improve welfare and production performances, different types of vaccines and **vaccination** techniques and programmes are employed either pre and, post hatch or at the maternal level. The primary goal of vaccines is to prevent and control contagious diseases. The type of vaccine as well as the vaccination programme and technique used by poultry farmers are influenced by several conditions such as the type of production, local pattern of disease, costs, and potential losses.

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INTRODUCTION

Poultry species, especially domestic chickens are one of the most widely reared animals for either their meat or eggs. Due to the lack of any religious, cultural, or traditional condemnation against the consumption of poultry meat and egg, it is considered that poultry meat, egg and their products are widely consumed compared to other livestock species. Poultry species are very cheap to buy, they do not require large hectares of land, are characterized with a high production rate as well as capable of adapting and thriving in most geographical areas (Marangon and Busani, 2007). It has been stated that there are more than 23 billion poultry in the world and these poultry are reared in different types of housing or production systems where they provide mainly meat and eggs for human consumption as well as manure for fertilization of crops (Mottet and Tempio, 2017). Again, according to Mottet and Tempio (2017), the poultry industry emerges as the most efficient sub-sector in the livestock industry due to its use of natural resources as well as providing protein to feed the global demand.

To continue feeding the growing population and also meet the rising demands for poultry protein, genetic selection for high egg production and larger breast meat has left some negative impacts on the immune ability or defense mechanism of modern-day poultry making them prone to diseases. Unlike their ancestors the red jungle fowls that lived in the wild and were resistant to a lot of diseases, modern day chickens are raised in enclosed shelters where the environmental conditions are manipulated or controlled by human beings. Global and environmental changes as a result of climate change has increased the rapid emergence and the spread of poultry disease making the immune defense system of poultry species incapable of protecting the birds from infections and sudden death. Several authors have stated that the occurrence of poultry diseases are caused by several factors such as the climate, farm hygiene and biosecurity, geographical location, type of production, age, sex, species, vaccine failure and immunization status (Chakma, 2015; Abbas et al., 2015; Hassan et al., 2016; Rashid et al., 2013a, 2013b; Talukdar et al., 2017). When poultry are exposed to various kinds of immunosuppressive agents, their health and welfare are damaged as a result of decreased innate and acquired immunity thereby decreasing the production efficiency of the poultry (Umar et al., 2017). Again, the movement of farm personnel in and out of the farm possess a high risk of transmitting contagious disease to the poultry which subsequently affects production and may lead to economic losses. Calnek et al. (1997) stated that poultry species are prone to several disease-causing organisms such as bacteria, fungi, viruses and parasites and clinical disease and death may occur when susceptible birds are exposed to infectious disease causing agents (Sharma, 1999). The widespread and distribution of Newcastle disease (ND) and some zoonotic diseases such as Avian Influenza (AI) cause a detrimental effect on the poultry sector and the human population as well (Marangon and Busani, 2007). Because of globalization and the possible persistence as well as the spread of disease agents through domestic and wild reservoirs, the risk of transmission of certain trans-boundary poultry diseases to previously unaffected areas has increased (Beutler, 2007). Several other factors such as season, high levels of ammonia, prior infection with immunosuppressive agents, age of the bird and prior infection with other respiratory disease agents may increase the risk of exposure to AI in poultry (Spackman and Pantin-Jackwood, 2014).

To manage or prevent the spread or the outbreak of diseases, the poultry sector carries out routine vaccination against some known and persistent poultry pathogens of specific economic importance that is common within their geographical boundary (Isegbe et al., 2014). The use of vaccines is a common practice and has gained substantial interest in the poultry industry. Scientists are still researching and developing new vaccines that are strong and effective against the existing and deadly poultry diseases such as coccidiosis, ND, and AI. The main aim reason for using vaccines is to stop or prevent infectious poultry diseases. Furthermore, vaccines are also used at the farm level to prevent, stop, avoid or to minimize the occurrence of clinical diseases to ensure sustainable production (Marangon and Capua, 2006). According to Isegbe et al. (2014), a biological preparation that enhances immunity to a specific disease is known as a vaccine and these vaccines are often made from weakened or killed forms of the microbe, its toxins or one of its surface proteins

(Smith, 2007). Griffin et al. (2002) also defined a vaccine as a preparation of a weakened or killed pathogen, such as a bacterium or virus, or a part of the pathogen's structure that upon administration stimulates antibody production against the pathogen however not having the ability to cause a severe infection.

The type of vaccine as well as the vaccination programme and technique used by poultry farmers are influenced by several conditions such as the type of production, status of maternal immunity, availability of other vaccines, local pattern of disease, costs, and potential losses (Marangon and Busani, 2007). Furthermore, several factors must take into consideration before choosing the right vaccination programme which includes the type of poultry production (e.g. commercial or rural), the organization of the industry (e.g. vertical integration), the density of different bird species, the prevailing disease situation, vaccine availability, the, the prevalence of other diseases, the resources available (e.g. manpower and equipment) and the costs involved. To improve disease control and the production performance of poultry birds, the rightful planning, attentive usage and the administration of the rightful dosage of the particular vaccine has to be given the necessary attention.

This work aims to provide information regarding the use of vaccines in the poultry industry as well as the type of vaccines available, their advantages and disadvantages, mode of application (method of vaccination) and some causes of vaccine failure.

Types of vaccines used in the poultry industry

As the world develops or progresses due to scientific findings and technological advancement, development in various aspects of the poultry sector including disease management has also been achieved. Furthermore, vaccination is an important component of commercial flock management strategies in many countries, as it is the most cost-effective means of preventing and controlling the spread of economically important diseases such as Marek's disease, Newcastle disease and infectious bursal disease (Zander et al., 1997). They stated that several disease-causing organisms are naturally resistant to many antibiotics and this has led to alternative search for other immunological means of controlling poultry diseases. Several researchers have classified or described vaccines based on either their nature, structure or the intended purpose. However conventionally, vaccines are categorized as those having a live virus and those containing inactivated virus emulsified in oil (Senne et al., 2004). Inactivated vaccines are normally used for laying or breeding flocks (Cargill, 1999). Also, in research conducted by Rabie and Amin Girh (2020) the authors stated that conventionally, the development of a bacterial vaccine is based on whole bacteria, and they are divided into two groups: living vaccines and inactivated (killed) vaccines.

Again, in a research conducted by Griffin et al. (2002), the authors classified vaccines and gave various definitions to each of the classified vaccines as written below;

Killed (Inactivated) vaccines (KV) and toxoids; these are either components of an organism, killed microorganisms, or the by-product of an organism. A huge number of organisms and adjuvants (aluminium hydroxide or oil) to create adequate immune response are used by killed vaccine products. To enhance the immune response by increasing the stability of the vaccine in the body as well as to stimulate the immune system for a longer time, an adjuvant is used.

Subunit vaccines; A type of a killed vaccine that contains other microorganism or only a portion of the virus is known as subunit vaccine.

Autogenous bacterial vaccines (Autogenous Bacterins); These vaccines are created from disease causing organisms that have been isolated from sick animals in the flock and in order for this vaccine to be created, the disease-causing bacteria are grown in culture, killed as well as mixed with an adjuvant.

Modified live vaccines (MLV); This type of vaccines contains a small amount of a bacteria or a virus which has been subjected to alterations or changes to render it incapable of causing clinical disease however capable of infection and also multiplying in the animal.

Chemically altered vaccines; in this type of vaccines, there are modified or altered live organisms that have been grown in a media with adjusted or controlled levels of certain chemicals that trigger and amplify the mutation of the organism as well as change the metabolism of the organism to alter its ability to cause disease.

Other authors have given other descriptions of the vaccines mentioned above. It has been stated that inactivated (killed) vaccines are produced from whole bacterial preparation with an inclusion of an adjuvant and they are inactivated or killed by either heating at 60 °C for 1 h as in campylobacteriosis (Widders et al., 1998), using chemicals as in salmonellosis (Duchatel et al., 1998) and in fowl cholera (Khafagy et al., 1999) or radiation as in *Pseudomonas* infection (Mohamed et al., 2002). Toxoids as metabolic product vaccines (Fukutome et al., 2001) and subunit vaccines are produced from outer membrane proteins (Abd-Aty and Rabie, 2003), whole-cell proteins and flagellin (Rabie and El Fakar, 2004), fimbrial and pilus proteins, and lipopolysaccharides (Shujian et al., 1996).

According to Jackwood et al. (2010) it can take up to 1-year to attenuate a field virus, however, rapid attenuation can sometimes be achieved through a combination of heat-treatment and limited egg passage.

Table 1. Some differences between live and inactivated vaccines

	Live vaccines	Inactivated vaccines
1.	Cheap to produce	Expensive to produce
2.	Mass and individual vaccination in a form of spray or drinking water or dipping the eye water	Individual injection needed
3.	Presence of a living organism	Do not have any living organisms
4.	Less stable during storage	More stable during the storage period
5.	Provides strong immunity	Provides weak immunity
6.	Less risk of causing allergies	High risk of causing allergies
7.	Requires less labor	Labor intensive
8.	Susceptible to existing antibodies such as maternal immunity available in birds	Having the ability to produce an immune response in the presence of an already existing antibody
9.	Its stimulates immunity (for example trachea or gut)	Local immunity may be restimulated if used as a booster however the secondary response is poor or absent
10.	Characterized by rapid onset of immunity	Normally, slower onset of immunity
11.	Adjuvating live vaccines is not common	Adjuvating killed vaccines is frequently necessary

Other types of vaccines described by Moyle et al. (2007) are as follows;

A. Recombinant-vector vaccines; This type of vaccines are produced by the removal of the genes from the pathogen that leads cells to create antigens and after that inserting these genes (recombine them) into the DNA of a non-pathogenic microbe also known as a vector. The newly produced or created vector will be used to infect the host, and this vector will replicate or multiply as well as express the antigens of the virulent pathogen leading to an immune response. One of the substantial and enormous importance of this type of vaccine is that the recently produced or engineered vector is live and hence can be used in a similar procedure to other live vaccines, however creating milder symptoms after vaccination. Strategies created for the production of recombinant vaccinia viruses have been readily adapted to the construction of recombinant viruses based on fowl pox virus (rFPV), and also avian influenza, Newcastle disease, Marek's disease and infectious bursal disease antigens expressed by the rFPV have been shown to be an effective vaccine in the poultry sector (Boyle and Heine, 1993).

B. DNA vaccines; this type of vaccine is also referred to genetic or DNA immunization. These vaccines are produced by separating the genes (the DNA) that relocates the pathogen cell to produce antigens and this DNA is directly injected into the muscle tissue. To allow the animal cells themselves produce antigens and in turn immunity against the disease, the DNA is incorporated into the cells within the animal's body. There are several advantages of this DNA type of vaccine which includes; 1. The ability to create long- lived immunity with a single injection. 2. To protect animals from multiple diseases, DNA from several pathogens could be combined with a single injection. 3. These types of vaccines do not require any special handling or refrigeration because they are extremely stable.

Table 2. Some advantages and disadvantages of certain types of vaccines

i.	**Killed vaccines and Toxoids**	
	Advantages	**Disadvantages**
1.	Stable in storage	More likely to cause allergic reaction
2.	Less risk of contamination	It takes time for immunity to develop
3.	No risk of spreading disease	May not produce strong immunity
4.	No risk of changing back to a virulent form	At least 10 days apart are required for two initial doses
5.	Available for wide range of diseases	Compared to modified live vaccines, it produces a narrower spectrum of protection
ii.	**Modified live vaccines (MLV)**	
	Advantages	**Disadvantages**
1.	Less expensive	Capable of mutating to a virulent form
2.	Rapid immune response than killed vaccines	May cause disease in birds with weak immune system
3.	Provides huge range of protection than killed vaccines	Handling with excessive care
iii.	**Chemically altered vaccines**	
	Advantages	**Disadvantages**
1.	Very safe to use	Does not provide rapid immune response as MLV
2.	More rapid protection than killed vaccines	Strong or long lasting immunity may not be produced
3.	No risk of changing to a virulent form	Mixing and handling has be done with excessive care and caution

Source; Griffin et al. (2002).

The development of a vaccination program

The development of a feasible and efficient vaccination program is very crucial as its form part of the production cost and also determines the efficacy of the vaccines. Based on the literatures gathered, some of the information to consider when developing a vaccination program includes;

A. For each animal age group, outline a vaccination schedule.

B. Rinse or clean reusable syringes in boiling water or use new sterile syringe.

C. For every type of animal select the appropriate needle size.

D. Check on the label and follow the precautions, warnings, and withdrawal time.

E. To identify a particular disease problem, consult a veterinarian.

F. To select an appropriate vaccine, consult a veterinarian.

G. Vaccines should be stored and handled as instructed by the manufacture.

H. Needles that are damaged or contaminated should be changed.

Method of vaccinations (vaccination techniques and procedures)

In poultry species, the most cause of a vaccine failure is as a result of poor administration techniques and in the USA, based on surveys, it was estimated that 75-85% of vaccines are incorrectly administered (Cargill, 1999). To improve disease control and economic performance of poultry species, detailed planning and necessary attention of a vaccination programme has to be employed. Several factors such as the animal welfare, avoidance of tissue damage and stress may influence the chosen method of vaccination and the major factor in choosing the method or technique of administration to poultry is the ease of administration or application (Vermeulen et al., 2002). The success of vaccination depends on the skills of the vaccine administrator in administering a full dosage of the vaccine to each bird (Breytenbach, 2004).

Several methods of vaccination or vaccine administration have been described by several authors such as Cargill (1999), Vermeulen et al. (2002), Larrabee (1983), Santos et al. (1997), De Wit and Van Gerwe (2004) and Dorrestein et al. (1986) as follows;

A. Administration through drinking water; Vaccine administration through drinking water is an efficient technique of vaccine administration for most live vaccines, especially for avian encephalomyelitis and infectious bursal diseases where the target organ is the gut.

B. Eye drop technique or administration; for the administration of a live respiratory virus vaccine, this method is one of the most effective. Both local and humoral immunity are enhanced by this method due to the presence of the Harderian gland behind the third eyelid as well as each bird receiving a full dosage of the vaccine.

C. Nebulisation or spray administration; Spray administration, which is an effective vaccination technique for the respiratory virus is employed to day old chicks in delivery boxes or birds in poultry units.

D. In-ovo administration; In this method, between embryonic ages 17.5-19 days, a vaccine is administered to fertile eggs via the air cell with a help of a device designed by a company known as Embrex. For Marek's disease vaccine and some infectious bursal disease vaccine, this method has proven to be an effective means of administration and may also be an effective method for other type of live vaccines.

E. Injection; One of the common routes for the administration of oil and aluminium hydroxide adjuvanted vaccines and some live vaccines.

F. Transfixion and scarification; A technique in which the vaccine is administered into the thickness of the skin and this method is used completely for the vaccination of fowl pox. The skin of the wing web, the foot, or the skin of the thigh is the most common site of administration.

G. Feed medication; Drug administration through feed is regarded acceptable, safe and a reliable method of drug administration.

Table 3. Vaccination route generally used in poultry; some advantages and disadvantages

Site	Vaccination technique	Advantages	Disadvantages
On-farm	Drinking water	1. Ease of administration 2. Saves labor	1. Improper administration 2. Inactivation by impurity 3. Birds stressed by water starvation
	Spray	1. Minimized bird stress 2. Cheap 3. Mass application 4. Good mucosal immunity	1. Possible respiratory reactions 2. Possible inconsistencies of vaccine dosage
	Intraocular/Nasal drop	1. Uniform local and humoral immunity 2. Effective and accurate for live vaccines	1. Labor intensive
	Wing web	1. Gives about 95-100% immunity or protection	1. Labor intensive 2. Possible infection at the injection site
	Subcutaneous/ intramuscular	1. No risk of spread of disease 2. Uniform level of immunity 3. Less level of adverse reaction	1. Expensive 2. Labor intensive 3. Regular sanitization of equipment 4. Possible damage of localized tissue
Hatchery	In-ovo	1. Stimulation of both innate and adaptive immune response 2. Early protection	1. Skill needed 2. Expensive equipment 3. Possible contamination of embryo
	Spray	1. Cheap 2. Good mucosal immunity 3. Minimized handling	1. Possible respiratory problems
	Subcutaneous/ intramuscular	1. No respiratory problems 2. Uniform level of immunity	3. Regular sanitization of equipment 4. Possible damage of localized tissue 5. Birds are stressed

Source; Marangon and Busani (2007)

H. Parenteral administration; in this method, the drug is administered by intravenous, subcutaneous, or intramuscular route. This technique is known to be stressful, time demanding and can cause a substantial residue problem. This method has an immediate positive effect as high blood and tissue levels are reached within few hours of administration.

I. Oculonasal; One of the effective route of vaccine administration is through the oculonasal route against respiratory pathogens causing respiratory diseases.

Factors affecting the efficacy of a vaccine

There are several factors that affect the efficacy of a vaccine or interfere with the efficacy of a vaccine in poultry. According to Griffin et al. (2002), a vaccine failure occurs when it does not develop adequate immune response to protect the animal from any kind of infection and this is commonly due to some pre-existing antibodies, heat stress, weather stress, disease and parasitism. Also, Isegbe et al. (2014) reported that when a chicken does not develop sufficient antibody titer levels due to cold chain break, stress, management error or immune-suppression with other co-existing immune compromising diseases a vaccine failure occurs. The causes of vaccine failure can be divided into two major factors and that is the antigen factor or the host response (Sharif and Ahmad, 2018). The virus serotype, level of protection, handling, diluent used, route, stress, maternal immunity, immunosuppression, sanitary status, genetic factors and hygiene practices are some of the factors that influences the efficacy of vaccines (Marangon and Busani, 2007; Butcher and Miles, 2009). Furthermore, it was stated that the success of a live vaccination also depends on the vaccine strain being injected into the correct target cells (Breytenbach, 2004). According to Gough and Alexander (1973), the authors compared the efficacy of a Newcastle disease vaccine applied through two different routes, the aerosol route and through drinking water and the authors concluded that administration through drinking water resulted in a delay of immunity development where the aerosol method initiated the highest serological response. Group size and sample number, vaccination schedule, vaccine storage, ventilation quality, vaccine dosage, vaccine quality, age and maternally derived antibodies, and vaccination programme are some of the factors that may influence the efficacy of a vaccine or cause a vaccine failure (Griffin et al., 2002). Another critical or crucial factor in achieving optimal vaccine efficacy is the antigenic matching between vaccines and the field viruses therefore the selection of an initial vaccine that is a good antigenic match to the virus is very important (Swayne et al., 2014).

CONCLUSION

The use of vaccines is widely accepted in the poultry industry and these types of vaccines are generally divided into live or inactivated vaccines. The main aim of using vaccines is to enhance immunity leading to resistance, prevention or avoidance of the spread of infectious diseases. To successfully implement a vaccination programme, the local conditions, the characteristics of the poultry producing sector, eco-epidemiological situation and the availability of adequate resourceshave to be taken into consideration. Vaccination can be done at the hatchery or at the production units and the type of vaccine to be used as well as the mode of application has to be critically examined to ensure no errors or harmful effects on both the animals as well as the farmer. Considerable effort and high level of organization are needed for an effective vaccination programme. The type of vaccine chosen influences the acquisition of immunity and the route of administration determines the rate at which immunity is obtained. All the different methods of vaccine administrations have their advantages and disadvantages. Vaccination does not guarantee immunity as there are several other factors such as stress, maternal immunity, handling and storage that may inhibit or cause immunosuppression.

Conflict of Interest

The authors have declared that there are no competing interests.

Authors Contribution

All authors have made equal contributions to the writing

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