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INITIATIVE ON
Sustainable Animal Productivity

Participatory Indigenous Chicken Breed Improvement Program (PIC-BIP): A guide to setting up and managing an open nucleus breeding program supported by artificial insemination using Skoeuy chicken of Cambodia

Participatory Indigenous Chicken Breed Improvement Program (PIC-BIP): A guide to setting up and managing an open nucleus breeding program supported by artificial insemination using Skoeuy chicken of Cambodia

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INITIATIVE ON
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1 Introduction

Participatory indigenous chicken breed improvement is a process through which smallholder poultry producers are regularly involved in enhancing genetic potential. Their involvement includes defining breeding goals and priorities, selecting or providing indigenous chicken breeds to be considered, evaluating the improved birds, engaging the breeders/scientists, and multiplying and marketing the genetically improved chicken. The goal is to enhance meat and egg production and sustain the existing free-range system. All management decisions are taken and implemented by the community and accompanying research is based on full farmer participation.

In participatory indigenous chicken breed improvement programs, nucleus farms are needed to keep elite chicken where continuous genetic improvement is expected to occur. The nucleus farms can be owned by private chicken companies or farmers interested in the chicken strain under consideration. It should be financial motivation that attracts and keeps them involved. Apart from the nucleus farms (selective breeding), additional smallholder farmers who keep chicken and conduct performance evaluation and multiplication are required. These farms receive chicken from the nucleus farms and provided feedback on the performance of the chicken. In cases where open nucleus breeding programs are preferred, these smallholder farms will give the best cocks back to the nucleus flock to advance the improvement. On-farm and on-station testing of the chicken is also required to determine the magnitude of genotype by environment interaction.

The preconditions for a breeding program can be summarized as below:

Selective breeding exploits the substantial genetic variation present for most traits with desirable qualities. The main benefit of selective breeding is that genetic improvement remains permanent and the genetic progress per generation will be transferred to generations.

- There must be variation between chickens for the traits under consideration. If all the chickens share identical phenotypes, there are no individuals with higher-than-average trait value to select.
- A portion of this variation must be due to genetic differences since it is only the genetic variation that is transferred to the next generation through eggs and sperm.
- The life cycle of the species must be known and able to be controlled since it must be possible to evaluate progeny for trait characters, subsequently select parents for the next generation and cross them in a controlled manner.
- Individual chickens must be identifiable (through various tagging methods) to keep track of their pedigree.

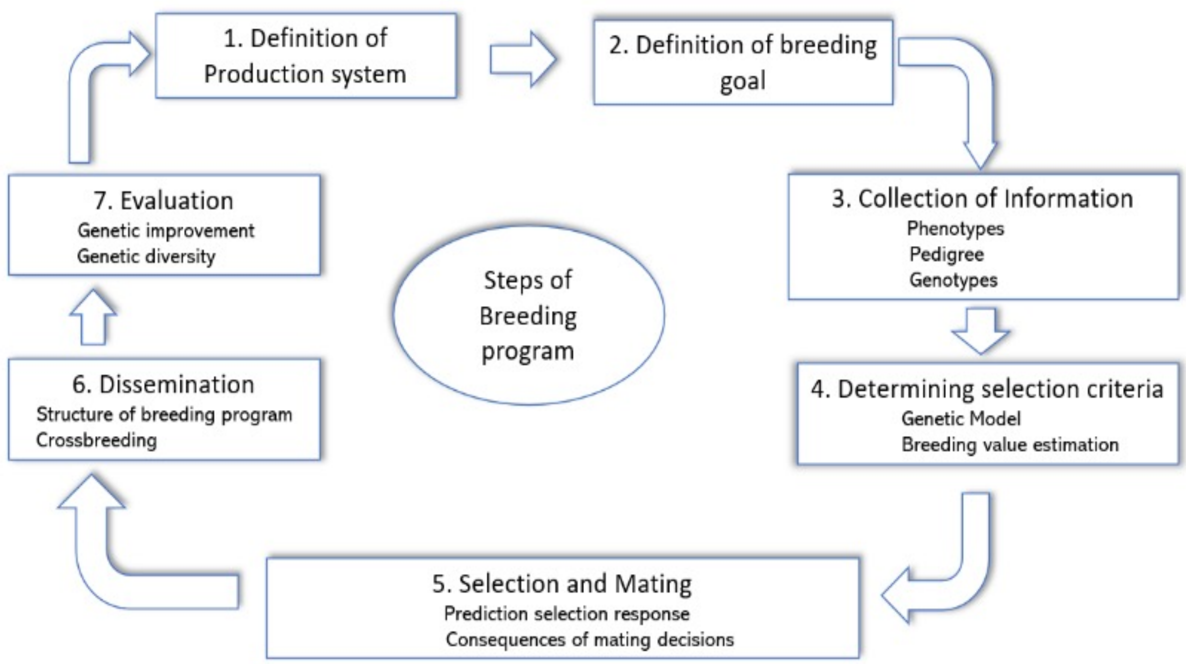
Figure 1. Mixed flock of Skoeuy bicolour, Tram Kak, Cambodia.

Phot credit:ILRI/Wondmeneh E.

2 Steps

The overall process and steps in a typical breeding program can be summarized in the scheme below. The steps need to be followed to arrive at the overall aim are shown in Figure 2 below.

Figure 2. Steps in a typical breeding program.



3 Defining the selection and production environment

The locations where the improved chickens are kept and where the birds end up are the two most important aspects of the breeding program. The selection environment is where the selection candidates are kept and mated and the best individuals selected. They are provided with ideal/appropriate conditions to help them reveal their genetic potential. The breeder should consider the expression of the traits of the birds in their destination environment. When there is a big difference between the selection environment and the actual production environment, there will be a difference in expression of the traits of interest. Where chickens are destined for a substandard environment, exposing the selected chicken to fewer ideal conditions might help the selected birds to best fit to the actual environment.

In most cases, many environmental factors, which can be systematic or random, influence quantitative traits in an animal. In a breeding program, a significant goal is to obtain the best possible estimate of the genotype of each animal. This estimate defines the animal's breeding value and is typically predicted based on phenotypic records of the animal and its close relatives. The influence of the environmental factors tends to mask the underlying genotype and should therefore be minimized to obtain the most accurate estimates of the animal's breeding value. There are several ways to do this. The preferred option is that the different genetic groups to be compared (families or flocks) be reared under conditions as similar as possible in terms of feed, water, temperature and light regime. In practice, this can be achieved by communal rearing of families in the same housing or cages. The effect of systematic environmental factors like age, sex, cage, farm and feed can be reduced by estimating correction factors and adjusting the data.

3.1 The selection environment

The selection environment is where the actual selective breeding happens. In Participatory Indigenous Chicken Breed Improvement Programs, selection or genetic improvement is conducted with in the villages. This gives the end users more authority in the direction of the improvement.

Below are the suggested components of PIC-BIP:

1. Nucleus farms are where the breeding or selective breeding is conducted. These are farms with experience in poultry rearing and hatching replacement flock. Nucleus farms must have a housing facility that enables control of the chicken, tagging and data collection from individual chickens. Pedigree information must be recorded and followed properly while hatching the eggs. At open nucleus farms, better performing chicken can be brough back in the form of semen (artificial insemination) to minimize the risk of disease introduction. The nucleus farms collaborate with individual smallholder producers who receive new generations for testing and send back feedback and better performing chicken.

2. Participating farms are ideally smallholder farms regarded as the production environment where the improved birds are expected to perform. This is part of the dissemination plan once the goals of the breeding program are met. The farms are the place where birds can be tested and the magnitude of the genotype by environment interaction measured. These farms continuously receive (improved) birds from every generation and manage them. When they came across best birds within their flock, they give them back to the nucleus farms (breeder farmers). Birds that are meant for substandard management conditions should fit the smallholder poultry production system.

3 Non- government/government /research provide critical support for program success. Their backing includes training of both nucleus farms (breeders) and participating farms on how to better manage the birds for effective and continuous genetic gain, as well as data recording and linking the system to potential multipliers.

4 The breeding goal traits

The breeding program aims to address the needs of the smallholder farmers and the breeding goal needs to be set during the planning stage. The breeding goal indicates the traits of interest, ideally identified through communicating directly with the end users, and thus dictates which traits to consider and the direction of the improvement. Previous studies conducted in Amhara Region of Ethiopia through the African Chicken Genetic Gains program found that farmers are interested in meat-related traits such as growth rate, weight for age and feed efficiency as well as egg production traits such as age at first eggs, egg size and number.

4.1 Understanding chicken biology

Chickens are homoeothermic and maintain their body temperature at a roughly constant level regardless of environmental temperature. The average body temperature of a hen ranges between 40 °C and 42 °C. The environmental temperature at which the birds do not need to modify their metabolism to generate or get rid of heat is the so-called zone of thermoneutrality, ranging from 13–24 °C. However, the optimal environmental temperature for layers is between 18–24 °C.

Chickens have no sweat glands for transpiration and losing physical heat. Chicken producers must consider this for successful poultry farming. Birds that live beyond their comfort zone will undergo stress to live and perform unless some corrective measures are taken. As the temperature of the environment increases above the comfort zone, chickens limit their movement, eat less and drink more water to cool down. Most of the water is excreted in the faeces, resulting in wet droppings. The birds also try to move away from others and move to a cooler surface to alleviate the heat. They extend their wings away from their body and expose skin areas with no feathers, thereby increasing blood flow to peripheral areas such as the wattle, comb, claws and wings. If these actions are insufficient to cool down and keep the body temperature constant, the bird starts to pant. The additional respiration leads to an increased loss of carbon dioxide, decreasing the blood's concentration of bicarbonates and negatively affecting eggshell formation. It also causes a rise in the blood's pH level, thus making the bird more vulnerable to respiratory alkalosis. If the body temperature reaches 46 °C, panting stops, and if it exceesds 47 °C, death occurs.

Quality parameters of fertile eggs:

- **Medium-sized, not too large or too small**
- **Fertile**
- **Free from cracks**
- **No rough shells**
- **Not misshapen or spotted**

4.2 Formation of breeding flocks

Enough chicken should be available to set up the breeding program by collecting either birds or fertile eggs from the field. Both options have their challenges. Collecting birds from the village might appear an easy option but it presents a higher mortality challenge due to the confining of free-range chicken. The birds die from the stress of confinement and diseases that they might have carried. In the second option, the eggs collected from the field can be fertile or infertile, fresh or old, and can cause poor hatchability. Therefore, a greater number of eggs to cater for potential hatchability problems needs to be collected. It is necessary to pay higher prices for fertile eggs to motivate farmers to bring high-quality and fresh eggs. Eggs were collected based on the criteria indicated in the box.

Eggs must be packed in trays, well wrapped in boxes and securely positioned to prevent unnecessary bumps and ensure safety during transport. The eggs should be left to settle and cleaned following the proper procedure upon arrival. They should then be properly disinfected to avoid the introduction of disease-causing agents into the hatchery. Candlelight should be used to remove infertile or dead eggs from the setter. It is essential to apply the proper hatchery procedures (providing proper sanitation, temperature, relative humidity, turning, ventilation and position of eggs) to produce best quality chicks. There is a direct relationship between the size of the egg and the size of the chick, just as between clean and fertile eggs and the quality of chicks.

4.3 Selection and management of hatching eggs

Fertile eggs are critical inputs in the multiplication of the flock under genetic improvement. Necessary precautions should be taken as minor physical defects on eggs may have huge consequences for generations to come. It is important select eggs from hens that are well developed, mature and healthy. Eggs from young flock are usually small and low in fertility, easily fragile and thin-shelled compared with the older flocks.

The size of hatching eggs is important because there is a high correlation between the size of the hatching egg and the size of the chick hatched. As a general guideline, the desirable size is approximately 56.7 g. Eggs that are large in proportion to the size of the hen producing them tend to hatch poorly. Those in which the proportion of white to yolk is about 2:1 usually hatch better than others with wider or narrower ratios.

Only clean eggs should be used for hatching. Though the use of dirty eggs is discouraged, during shortages, they can be wiped clean using a damp cloth. Soiled eggs can be washed, though it may cause problems. If it must be done, the washing water should be warmer than the eggs.

Eggs with cracks, thin shells and an excessively misshapen appearance should not be considered. All hatching eggs should be tested for cracked shells. The easiest check is tapping two eggs together: if there is a resonant sound, both eggshells are sound but if there is a dull sound, one of the eggs is cracked and should not be used for incubation.

Utmost care should be takes in shipping or delivering eggs to a hatchery to avoid excessive shaking, which sometimes results in a condition known as tremulous air cells and which tends to lower hatchability. However, the likelihood of hatching is not affected negatively by the lower air pressure resulting from higher altitude.

4.4 Management of hatching eggs

All hatching eggs should be uniform in shape and size, and sound in shell. For excellent results, the proper care of the eggs before they are set in the incubator is very important. Even before incubation starts, the embryo is developing and needs proper care to achieve the maximum possible hatchability.

Egg storage is the time between oviposition (laying) and the start of the incubation process for hatching eggs. Storing eggs beyond two days leads to loss of hatchability and reduced chick quality. Below are tips to help maintain hatching egg quality.

- Collect eggs at least three times daily. When daily high temperatures exceed 30°C, increase egg collection to five times daily. Collect twice or thrice in the morning and once or twice in the afternoon.
- Slightly dirty eggs can be used for hatching. Do not wash but use a damp cloth with water warmer than the eggs if cleaning is necessary.
- Store eggs in a cool-humid storage area. Ideal storage conditions include 13°C temperature and 75% relative humidity. Never store eggs at temperatures above 24°C and at humidity lower than 40%. These conditions can decrease hatchability dramatically in a very short period.
- Store the eggs with the small end pointed downward. Alter egg position periodically if not incubating within 4–6 days. Turn the eggs to a new position once daily until they are placed in the incubator. Do not store eggs for more than 7 days before incubating. Do not use eggs stored for more than 3 weeks because hatchability drops to almost zero. Plan a regular hatching schedule to avoid storage problems and reduced hatches.
- Allow cool eggs to warm slowly to room temperature before placing them in the incubator. Abrupt warming from 13°C to 37.7°C causes moisture condensation on the eggshell that leads to disease and reduced hatches.

4.5 Maintaining hygienic conditions

A major source of contamination within the hatchery is poor sanitary condition of the hatching eggs. Thus, the sanitation of the hatchery depends on the hygiene standards of the breeder farm and on the frequency of egg collection. Good hygiene is required for higher hatching results (higher hatchability and chick quality). Therefore, protection of hatching eggs from contamination and day-old chicks from vertically transmitting diseases are priorities. The hatchery should be designed in such a way that eggs can get into the facility easily from parent stock farms and chicks can be distributed efficiently to the other smallholder farms or commercial farms.

To maintain hygienic conditions, the following procedures should be followed:

- Hatchery personnel should follow sanitary procedures in the facility.
- All external hatchery doors should be kept closed and locked to keep out unwanted visitors.
- Staff and authorized visitors should shower and change clothes (putting on hair nets, overalls, boots etc.) prior to entry.
- Vehicles and outdoor equipment must be disinfected before being allowed into the hatchery.
- Washing and disposal areas should be far away enough to prevent moulds and pathogenic bacteria from being carried into the hatcheries through poor ventilation systems.
- Proper ventilation should be maintained to avoid embryos and newly hatched chicks being infected with bacteria and moulds during incubation.
- Once the eggs have been cleaned and stored in the cold room overnight, they should be set into the incubator.
- Before setting, each egg should be labelled to indicate the hen that laid it.

4.6 Housing

Chicken houses in hot climatic areas should be constructed to support the release of body heat by radiation, convection, conduction or evaporation. Constructing open, also known as naturally ventilated, houses might be advisable in these areas. The houses should be built in an east-west orientation so that only the smaller side is exposed to the sun, preventing direct sunshine in the building and allowing the prevailing winds to facilitate ventilation. Neither buildings nor bushes that could obstruct airflow should be located nearby. It is advisable to plant grass around the poultry house to reduce the sun's reflection from the ground. When watered, the grass will also have a cooling effect through evaporation. Tall trees up to the height of the roof provide shade to the poultry house roof. In addition, the top of the house must have an open ridge at least a metre wide to allow cool fresh air from outside to replace the hot air inside.

4.7 Preparing for chick arrival

Cleaning and disinfecting are critical components of routine biosecurity in poultry farming and help to kill disease-causing organisms such as viruses, bacteria, parasites and fungi (moulds) that might be present on a farm at the end of a production cycle or after a disease outbreak. They involve the physical removal of foreign material like dust and organic material such as droppings, blood and, secretions.

Cleaning comes before disinfection and generally involves dry and wet procedures. Dry cleaning of equipment and facilities is done using a broom, brush, shovel and high-pressure washer to remove all debris and dust left by the previous flock. Wet cleaning involves the use of detergent/soap and water to soak and scrub the area and to remove the remaining organic material, dirt and grease. Commonly available detergent powders can be used. Wet cleaning reduces the risk of aerosolization (dispersal of a viral particles in the form of an aerosol) of the virus. Disinfection kills the disease agents left after cleaning or slows their activity, multiplication and growth.

After cleaning and disinfection, the poultry farm should be left vacant for two weeks before placing a new flock. Two or three days before occupation by the newly hatched chicken, the brooding house should be bedded with well dried and disinfected litter of sufficient depth.

4.8 Identifying and weighing chicks

Essential inputs and equipment such as vaccines, syringes, vitamins, tags and weighing balances must be prepared before the eggs are taken out of the hatchery. Chicks should be unloaded from boxes quickly, weighed and identified by attaching an aluminium wing tag. Brooding of chickens can be done either in the pens or in dedicated brooding houses. It can also be done using the whole poultry house if the temperature can be controlled. Almost similar outcomes can be realized in this way.

4.9 Brooding chicks

Brooding rings, lighting systems, bedding materials, feed and water should be placed in the brooding house. The brooding ring should allow easy access to the feeder, drinker and adjustable light source for monitoring. To ease adaptation to the new enivornment, provide the chicks with vitamin-mineral premix or a sugar solution. Gently warm water is preferable to very cold water for newly hatched chickens as it will affect digestion negatively.

Temperature control is the most critical factor during brooding. The ability of chicks to regulate their temperature effectively directly affects their ability to grow proficiently. One day old chicks should be housed at a temperature of 30–33°C and 40–60% relative humidity. Appropriate care should be taken to prevent exposure to drafts, resulting in wind chill. When the chicks are one week of age, the temperature should be reduced by 2°C and then lowered gradually until a housing temperature of 21°C is reached. During the brooding period, observing the birds assists in providing the most desirable temperatures. Birds that are cold huddle together in a very tight group. Chicks that are too hot pant and appear drowsy. Chicks that are comfortable are evenly dispersed within the brooder ring and remain active except during the rest periods.

The source of both light and heat in the brooder ring can be an infrared bulb hanging from the roof. In the first two days, lighting should be maintained for 20–22 hours per day at an intensity of 30–40 lux to encourage water and feed intake. Lux is a measure of the intensity of light that hits or passes through a surface. Bright light (30–50 lux) in the first 0–7 days helps the chicks to find feed and water and adapt to a new environment. After the first week, a slow step-down lighting program provides rest periods (establishes more natural behaviour of rest and activity/feeding).

Between the first day and the second week, chick feed can be placed on a newspaper or flat tray then moved to a round pan and finally to a bell/round feeder. This will encourage comfortable feeding and prevent wastage. Feed must be provided early in the morning at around 0700 hours for ad lib consumption, where feed is always available and the animal determines the quantity and frequency of feeding.

Figure 3. Brooding chicks using bulbs within a brooding guard in Tram Kak, Cambodia.

Photo credit: ILRI/Hoa H.

4.10 Feed management and handling

Feeding chicken should support the overall production target. Good quality feed should always be available to enable every bird to consume the essential ingredients, including the more refined part of the feed. Birds do not consume powdery feed, therefore the mash feed should have a good structure with added fat and/or oil. If the only mash available has fine particles, sprinkling water in the feeder eases consumption. It is good to understand that chickens barely eat during the hottest part of the day.

The feeding system should encourage a high daily feed intake for better performance. This can be supported by feeding management, optimal feed structure and palatability, especially if mash feed is used, which is expected. The lower the daily feed intake, the more difficult and more expensive it will be to achieve sufficient nutrient intake for growth and the production of eggs.

Consumption and digestion of crude protein and carbohydrates, mainly starch, results in increased metabolic heat production, which can lead to heat stress in poultry. Crude protein should be adjusted to the lowest possible level by using synthetic amino acids while oils and fats should replace starch as a source of energy. On average, fat and oil have thrice as much energy content as cereals but cause much less metabolic heat increment. Therefore, it is essential to use fat and oil as raw materials for feed formulation in hot climatic regions. These ingredients also increase the palatability of mash feed, bind the fine particles in a mash structure and reduce selective feed intake, which could also causes problems.

Feed management involves the storage and handling of feed. The best store is a dry and cool place, safe from vermin such as rats and mice. The area or room should be closed and disinfected regularly to prevent growth of mould.

Feed for indigenous chicken can best be formulated using locally available raw materials while considering the needs of the birds. Unlike commercial chicken, finding the proper nutrient requirement for indigenous chicken might pose a challenge. However, one can create a hybrid formula from layers and broilers to feed dual-purpose heavy chicken. Lighter birds can adopt a layer diet until the right formula can be identified through nutrition optimization studies. There are several feed formulation applications and spreadsheet programs that can be used to achieve thisl. Table 1 shows a suggested feeding regime for dual-purpose chicken.

Table 1. Suggested feeding regime for dual-purpose chicken.

Week	Type of feed	Approximate daily feed consumed (grams)	Daily feed consumed + 40% allowance (grams)
1	Chick starter	15	21
2		25	35
3		30	42
4		35	49
5		40	56
6		45	63
7		50	70
8		55	77
9	Grower's diet	60	84
10		65	91
11		70	98
12		75	105
13		80	112
14		85	119
15		90	126
16		95	133

(Source: Various resarch reports)

Fresh and clean water should always be made available in the chicken brooding house. The drinking material should be cleaned at least once a day to prevent the development of germs and thereafter filled with fresh and clean water.

4.11 Vaccination

Vaccination is an important way of preventing diseases. Different regional epidemic situations require suitably adapted vaccination programs. Some of the vaccination methods used in poultry units are:

1. Individual vaccinations such as injections and eye drops, which are very effective and generally well tolerated, used in the hatchery for vaccination of chicks against Marek's disease
2. Drinking water vaccinations, used to protect chicks from Newcastle, infectious bronchitis, infectious bursal disease and avian encephalomyelitis
3. Wing web vaccinations against fowl pox

Table 2. Suggested vaccination program for indigenous chicken (Cambodia).

Day	Name of vaccine	Prevention	How to use	Other
5	Newcastle disease vaccine	• Live vaccine • Prevents Newcastle disease	• Drop in the chicken's eye • One drop/head	
11	Infectious bursal disease (IBD) vaccine	• Live vaccine • Prevents IBD	• Drop in the chicken's mouth • One drop/head	
15	Fowl pox vaccine Newcastle vaccine OL Vac	• Live vaccine • Prevents fowl pox • Dead vaccine • Prevents Newcastle disease	• Inject in skin of both wings • Inject in muscle • 0.5 ml/head	
21	Newcastle vaccine Hipraviar Clon/H120	• Live vaccine • Prevent Newcastle	• Mix with water • 2 litres/100 heads	
21	IBD vaccine	• Live vaccine • Prevents IBD	• Drop in the chicken's mouth • One drop/head	
25	Biofors FC	• Dead vaccine • Prevents cholera	• Inject in the skin or muscle • 0.25 ml/head	• Repeat in week 4 after first injection
45	Corypravac	• Dead vaccine • Prevents flu	• Inject in the skin • 0.5 ml/head	

Source: Medivet Company Ltd

4.12 Biosecurity and disease management

Biosecurity is a plan of practices designed to prevent the entry and spread of infectious diseases into and from a poultry farm. It requires the adoption of a certain set of protocols in line with this goal. For example, the brooder house should be located a separate compound away from adult birds. It is even better if the brooder and grower houses are built as separately fenced premises. In the management of these houses, one must practice the 'all in - all out' approach, whereby all the chickens that enter the production system at the same time also exit together to prevent reinfection of new flock from the remaining ones. Brooding can be done in deep litter for the first three weeks before shifting all the chicks to cages. Alternatively, the chicks can be brooded in specially designed brooder cages from day one.

To prevent entry of pathogens, the chicks should be free from infections when they arrive. Indicators of poor health include a mortality rate of above 5% in the first week, loose droppings, wet bedding material, discharge from the eyes or nostrils, hobbling and inactivity. The following are the three elements of biosecurity procedures in a poultry farm.

1. Segregation and traffic control: This is the most effective form of biosecurity to prevent contamination. It involves:

- Preventing disease agents from entering the farm by keeping potentially infected chickens and contaminated objects such as clothing, footwear, vehicles and equipment away from healthy chicks through construction of physical barriers.
- Preventing unauthorized people from entering the chicken house.
- Preventing the entry of wild birds and domestic chickens from elsewhere and the mixing of chicken from different houses.
- Ensuring all workers or visitors wash their hands and feet with soap before entering the chicken house.
- Ensuring all workers or visitors change or cover clothes and footwear before entering the chicken house (wear farm clothing).
- Ensuring all workers or visitors clean and disinfect their footwear between sheds using a footbath or chang the footwear.
- Ensuring that only essential visitors, such as veterinarians and service providers, are allowed on the farm.
- Preventing chicken and egg dealers from entering the farm.
- Ensuring that the farm follows an all-in all-out management system.

2. Cleaning is the next most effective step in the removal of contaminants on a poultry farm. It makes objects visibly clean and removes 80% of contaminants. The list below indicates all the things that should be cleaned regularly.

- Vehicles
- Clothes and footwear
- Workers and visitors' hands and feet
- Equipment used on the farm (syringes, de-beakers, drinkers, feed pans, egg trays)
- Workers' clothes and footwear
- Workers' hands in-between jobs
- Poultry houses (inside and outside)

3. Disinfection is a procedure to eradicate or kill microorganisms and/or inactivate unwanted viruses.

- Remove all dirt during the cleaning process.
- Use approved disinfectant only.
- Prepare a disinfectant solution in the right concentration.
- Apply disinfectant in the correct volume to ensure adequate contact time and to cover the entire surface.
- Prepare and apply disinfectant safely.

Table 3. Suggested biosecurity measures and procedures

Biosecurity measures	Procedures
Disinfectant foot dips	All workers and visitors must use foot dips/baths on entering the site, main gate and each pen. The dips/baths should be replenished every 4–5 days or when visibly contaminated.
Hand wash stations	Staff must wash their hands before starting work, after breaks and when changing activities.
Wheel washes and vehicle sprays	Every vehicle entering the site must pass through a disinfectant wheel wash or vehicle spray. The wheel wash should be refilled regularly to prevent dilution or contamination. Mobile equipment brought into the site from other units must also be washed and disinfected before entry.
Water line and drinker disinfection	Header tanks and pipelines must be cleaned regularly and disinfected with a non-tainting disinfectant to maintain water quality in the production cycle.
Bird sprays	Spraying a fine disinfectant mist or fog over the birds reduces infection and reinfection during outbreaks. It is particularly useful in preventing secondary bacterial infections (e.g. *E. coli*) following a virus attack.
Rodent and insect control	Implementing an effective insect and rodent control program keeps these pests at bay.
Work clothes hygiene	Clean work clothes should be available in every house. Protective clothes (boots, gloves, mouth protection etc.) should be issued to individual workers and worn as necessary.
Disposal of dead birds	Dead birds should be disposed of promptly, either by burning or burying.
Building hygiene	Thorough washing of all surfaces and equipment is essential to achieving the best results from subsequent disinfection.
Ventilation	Good ventilation promotes the entrance of large amounts of fresh air, dilution of microbes and reduction of disease build-up.
Litter removal	All old litter should be hauled to a remote part of the farm and composted to prevent the multiplication of pathogens.
Vaccination	Following a strict vaccination schedule prevents diseases occurrence.
Information access	Getting timely information related to disease occurrence in other farms, emerging disease threats and improved biosecurity measures is useful in preventing disease.

5. Collecting information

Information on phenotypes, family relationships and genotypes is critical to the successful implementation of the breeding program. At the onset, the program should set up protocols for the collection and establishment of indigenous birds from the field. These include on genotype source, number and quality, as well as the handling, storage and transporting of fertile eggs.

Based on the breeding goals set beforehand, a proper data collecting system must be available. Body weight is registered when the chicks are a day old, then weekly or biweekly until the selection criterion for body weight is met. Feed intake must be measured, preferably daily, until the birds are culled. Age at first egg, mortality, measurement of serum biochemical values etc. can be collected based on the breeding goal.

One of the most critical issues in managing breeding flocks is the challenge posed by parasites (coccidiosis and helminths). Coccidiosis is the most difficult health problem that the eggs can survive. Vaccination limits the severity of coccidiosis infection and shedding of eggs. For helminths, regular deworming is necessary.

5.1 Data recording

Data recording is essential in the generation of information required for genetic selection and other critical decisions in a sustainable breeding program. Estimation of breeding value calls for phenotypic data on selection candidates and their sibs and parents. As a result, the following data are collected from individual chickens in selective breed improvement programs:

- Body weight in both sexes: the hatch weight and subsequent body weight of each chicken are collected every week, for up to 16 weeks, using a digital weighing scale then analysed using a computer.
- Age at first eggs: the age (days) at which a female chicken first produced eggs is recorded. The ability of chickens to start egg laying early in life increases the farmer's profitability.
- Individual/group feed intake: each flock is provided with a certain quantity of feed a certain number of times every day. In the morning, before giving fresh feed, the previous day's leftovers are weighed to determine how much was consumed.
- Egg number and weight: egg production is measured until the age of 45 weeks, ideally using pens with trap nests. The best egg producers are identified based on egg production ranking and selected to produce eggs to be hatched as the next generation.

5.2 Ensuring proper data collection using a checklist

Participating in the community breed improvement program is a huge responsibility for the data collector. The data summary and analysis contribute to selection decisions and future orientation of the breeding program. Therefore, data collectors should be aware of the breeding program's objectives and direction and should understand:

- What data needs to be collected and along which parameters.
- How critical the data are.
- How to make effective use of time and other resources.
- The proper frequency of data collection.
- The intended forms of data analysis.

Data should be collected regularly and originally in the breeding programs, following the proper protocol and maintaining accurate records of definitions and coding. Properly collected adapt are easier to analyse. Most of the data from breeding farms are quantitative (numerical form), including body weight, feed intake, age at first egg, egg number and egg weight, and must be measured precisely. The following is a checklist for quality data collection:

- Understand the concept of the breeding program well.
- Know the parameters and types of data to be collected.
- Understand the data collection tools (paper and electronic).
- Regularize the visits and frequency of data collection.
- Never record data before taking measurements.
- Collect any relevant data on a separate document and date it properly.
- Communicate the data as soon as it is collected.

5.3 Correlating traits

Many quantitative traits are associated with each other and therefore show a varying level of covariation. The underlying reasons include the possibility that the same genes control these characteristics. In indigenous chicken breed improvement programs, it is necessary to keep an eye on attributes whose relationship is negative, such as body weight and egg number. Several selection experiments to increase part-year egg production have yielded positive egg number responses and invariably produced a concomitant reduction in egg weight.

6 Determining selection criteria

Setting a selection standard or set of standards ensures that birds meet or exceed certain requirements to be the parents of the future generations. Selection increases the occurrence of desirable qualities in the flock and decreases the occurrence of undesirable ones. Thus, breeding value is a major consideration when making this choice.

6.1 Estimating breeding value

Breeding value is the potential of an animal in the breeding program to transmit certain genes. It is part of the genotypic value that is transmitted from parent to offspring. This value cannot be observed in an animal but can be estimated from collecting, recording and analysing data on the animal or its relatives (e.g. selection index).

Estimated Breeding values (EBV) can be used to rank the birds and make selection decisions on parents of the next generation. Ideally, EBV should be unbiased and highly accurate. To this end, the animal model is a tool used extensively in quantitative genetics to estimate essential parameters such as additive genetic variance or heritability (Hill 2010). Best Linear Unbiased Prediction (BLUP) methods are used in the participatory indigenous chicken breed improvement program (Jeyaruban et al. 1995). The advantage of using BLUP is that:

1. It considers the systematic environmental effect.
2. BLUP is flexible and therefore more suitable as an operational tool.
3. It takes account of selection.

Selection based on the ranking of estimated breeding value is possible when population parameters are available. However, when all this information is not ready, the selection of birds is based on their own performance, also known as mass selection, whereby breeding value is estimated using the heritability (h^2) of the traits under consideration. Heritability is the proportion of the difference in phenotype (phenotypic variation), which can be explained by differences in breeding values (A).

An animal model that uses information from relatives and adjusts data for fixed effect will be used to estimate breeding value in this program. An implicit assumption of animal models is that all founder individuals derive from a single population. Models of genetic effects are maps relating phenotypes to parameters with genetic meaning and biological insight. These genetic models assume a genotype-phenotype linkage.

Estimated breeding values (EBVs) provide a measure of the breeding potential of an animal for a specific trait. They consider performance data collected on known relatives, the relationships between performance traits (correlations) and the degree to which traits are inherited from one generation to the next (heritability). EBVs are expressed in the same units as the recorded trait and compared to the average breeding value of a population (zero). A hen with an EBV of +20 for cumulative egg number is estimated to have the genetic potential to lay 20 more eggs per year compared to one with an EBV of 0.

7 Selecting and mating

Pen, stud, artificial insemination (AI), shift and flock are common mating systems that can be adopted based on the intended outcome. Pen mating is where the cock mates with a group of hens in a single pen. In this method, trap nests are required to identify the eggs produced from each hen. In stud mating, the cocks and hens are kept in separate pens and the hens are let into the male’s pen one by one at intervals. After mating, the females are returned to their own pen. AI is the manual depositing of semen into the reproductive tract of a female. This technique is approporiate when fertility is required but keeping many cocks is too costly. Under shift mating, the male is moved from one pen to another so that it has more mates through which it can be evaluated. And in a mass mating system, two or more males are mated with several females housed in single pen. In the participatory indigenous chicken breed improvement program, mass selection is applied, whereby chicken with superior characteristics (highly heritable breeds) are selected from a flock and then allowed to mate at random.

7.1 Selection intensity

Selection intensity is the proportion of male and female candidates selected as the parents of the next generation. In indigenous breeding programs, the proportion is set by considering the chicken mortality rate and physical deformities. When more of the required chickens per generation survive until selection age, more intense selection can be applied. In this approach, birds of both sexes are selected based on productivity and body weight. Eggs are collected for 21 weeks after egg production starts and selected for egg number. The decision for body weight can be made when the chickens are 16 weeks old by applying truncation selection (i.e. chicken that grow to 1,500 g at 16 weeks) to pick male and female candidates. Fifty cocks and 400 hens will be chosen in this breeding program to produce the next generation in each generation. For every generation, 4–5% of the best cockerels and 50–60% of the best hens will be selected as parents of the next generation.

7.2 Predicting the rate of genetic gain

The selection response per year is the function of intensity, accuracy, genetic standard deviation, and generation interval:

$$\Delta G = \frac{i * r_{IH} * \sigma_A}{L}$$

where ∆G = selection response per year expressed in trait unit

I = intensity of selection

rIH = accuracy of selection

σA = additive genetic standard deviation of the trait under selection

L = generation interval expressed in years.

The above equation is based on a single trait only but a breeding program may consider improving multiple traits (body weight and eggs) simultaneously. In this case, 'selection index theory' will be used to predict the rate of genetic improvement (Hazel et al. 1994). In multiple trait selection, ΔG is predicted for each trait separately in addition to predicting the rate of improvement in the breeding goal, H.

7.3 Selection scheme

The suggested selection scheme is shown in Figure 4. Based on fertility of the flock, the ratio of males to females can be 1:10 or 1:8. In situations where AI is applied, the ratio might be different. Figure 5 shows the suggested cage design and density for a nucleus farm. The flock will be started using 1,000 mixed sex day-old chicken. The chickens will be reared here until they are eight weeks old and their bodies are covered with feathers. They will then be tagged individually and transferred to six cage where the floor is suitable for them to stand (Figure 6).

Figure 4. Selection scheme followed in the indigenous chicken improvement program.

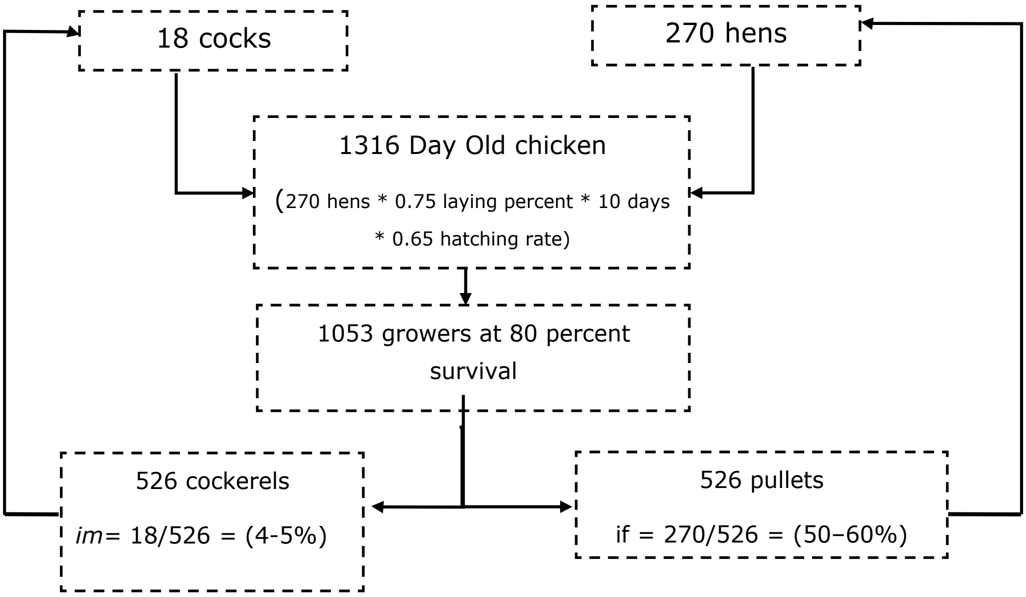
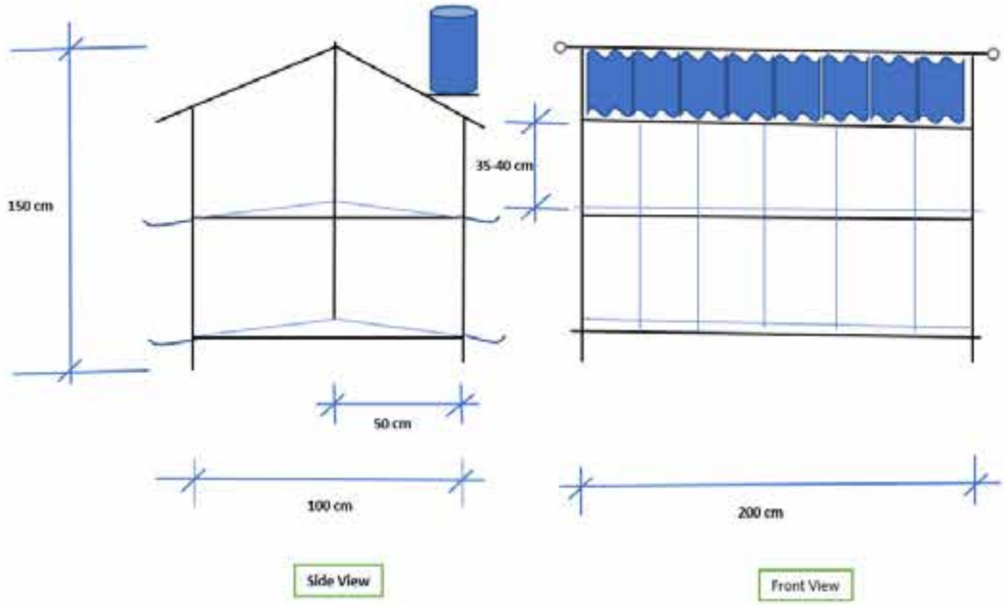


Figure 5. Design of a cage unit for individual monitoring of indigenous chicken.



Source: Wondmeneh E.

Figure 6. A cage for individual monitoring of indigenous chicken in Tram Kak, Cambodia.

Photo credit: ILRI/Hoa H.

7.4 Mating

This is the process that determines how maternally and paternally derived alleles are combined within individuals. In this breeding program, there will be three nucleus farms with a capacity of 288 breeding chickens kept in six cages. The total flock size in each generation will comprise about 864 chickens (54 cocks and 810 hens), and the mating ratio will be 1 cock to 15 females using artificial insemination.

8 Fertilization

Fertilization is a union of the sperm and the ovum, which must occur prior to the formation of the egg. Thus, if the hen has mated and she lays an egg, then that egg is fertilized. In chicken, fertilization can be achieved either artificially or naturally. Natural fertilization happens when there is no human aid and artificial fertilization occurs when there is human intervention in the collection of semen from the cock and depositing of semen into the hens.

8.1 Natural fertilization

The physical act of mating, or copulation, is the first step in the fertilization process. Under natural mating, copulation often starts with courtship. The cocks should show the desire to continue to mate throughout the life of the flock. When mating occurs normally, the male deposits semen in the hen's cloaca. Approximately 200 million sperm cells are deposited per ejaculation. Frequent mating is needed to ensure that relatively fresh and viable sperm are available in the hen during ovulation. Avian sperm have an extended life span due to the presence of sperm storage glands located in the hen's oviduct. This allows for stored sperm to travel from these storage tubules to the infundibulum, avoiding the need for daily copulation.

8.2 Artificial fertilization (artificial insemination)

AI is the manual transfer of semen into the female's cloaca. It is a two-step procedure: collecting semen from the male and putting it in the female. Additional steps such as semen dilution, storage and evaluation may also be required. The goal of AI is to produce a succession of fertilized eggs between successive inseminations. Therefore, weekly inseminations are needed to replenish the sperm population in the uterovaginal junction (UVJ) sperm storage tubules (SSTs).

Birds do not have an oestrous cycle that synchronizes copulation with ovulation. Instead, about 7–10 days before their first ovulation, hens mate and sperm ascend into the SSTs. At the onset of egg production, individual sperm are slowly released from the SSTs, transported to the anterior end of the oviduct, and interact with the surface of the ovum. Whether fertilized or not, over the next 24–26 hours, the ovum is transported though the oviduct, accruing the outer perivitelline layer (PL) in the infundibulum, the albumen in the magnum, the shell membrane in the isthmus, and the hard shell in the uterus (also referred to as the shell gland) before oviposition. If fertilized, the blastoderm in the first laid chicken egg consists of 80,000–100,000 cells.

AI is practised in poultry because it allows the keeping of few cocks. This is usually important in genetic improvement programs where higher selection intensity is applied to enhance genetic progress. Artificial fertilization is also useful when heavy males are required to mate smaller hens. Additionally, if properly executed, better fertility results may be obtained through AI than with natural mating. The average volume of semen is between 0.05-0.50 ml in light chicken breeds and 0.1-0.9 ml in heavy males and contains between 3-7 billion sperm cells/ml. (Mohan et al, 2018). For one insemination, about 100 million (0.1 billion) sperm cells should be sufficient, which means that with one cock, about 125 hens can be fertilized. Collected semen should be preserved at bout 8°C.

8.3 Application of AI in chicken

AI has been practised in chickens for several years. As the technique advances, materials and protocols have also changed, but the process is less sophisticated when using fresh undiluted semen. Below is the list of materials required to carry out AI in chickens

- Individual cages to allow easy handling of cocks
- Collection tubes
- Dilution fluid, depending on time until insemination
- Injection tube for insemination
- Microscope, if semen should be evaluated

Figure 7. Semen collection tools.

(simplified version by Wondmeneh E.)

8.4 Training of cocks and semen collection

Training the cocks before collecting semen will affect the success of the semen collection and overall AI procedure. It is therefore important to follow the right training and collection procedures.

- The cocks should be accustomed to the cage therefore they should be placed in the cages at least two weeks before starting semen collection.
- The cocks should be trained for at least two weeks, three times per week.
- For clean collection, the cloaca should be cleaned using a clean cloth and the surrounding feathers eliminated.
- Semen collection (milking) should be done before feeding or otherwise at least three hours after feeding to minimize contamination with faeces.
- Optimal semen collection can be done 3–5 times per week but even daily collection is possible.
- After fixing the cock, the back and tail-bottom should be massaged twice or thrice. When the tail is lifting, the same hand should be laid over the tail while the thumb and middle-finger should squeeze the cloaca gently, behind the exposed penis area.
- At the same time, the thumb and index finger of the other hand should put pressure under the cloaca to support the ejaculation, while keeping the collection tube in the little finger to be positioned under the cloaca.
- Avoid getting faeces into the collection tube.

- When no pedigree records are kept the semen of different cocks may be pooled to get a bigger sample of 'mixed-semen'.

Figure 8. Semen collection at Debre Zeit Research Center, poultry research facility, Ethiopia.

Photo credit: ILRI/Wondmeneh E.

8.5 Inseminating the hens

There are two ways of using the semen, fresh or diluted using appropriate fluids. Undiluted semen must be used within half an hour to avoid the loss of viability through temperature and handling. If diluted in a 1:1 ratio with a dilution solution, it can be kept for about an hour without refrigeration. After dilution, it should be cooled until 2–5 °C and can be used in 4–6 hours. With older semen, the size of the doses for insemination should be increased.

Inseminating the birds requires skill and good experience. The semen should only be deposited into the left oviduct because only the left side of the hen's reproductive system is functional. To expose the left oviduct, it is necessary to apply pressure on the left side of the belly area. As most of the eggs are laid in the morning, it is better to wait until after the laying time for successful insemination. The procedure should be done twice a week for the first time, but once a week is enough afterward. Semen must be deposited about one cm deep into the oviduct and the inseminators should always be gentle. Figure 9 shows the correct procedure.

Figure 9. Inseminating hens: Everting cloaca by pressing from the left side using the thumb and forefinger then depositing semen into the left side of the oviduct.

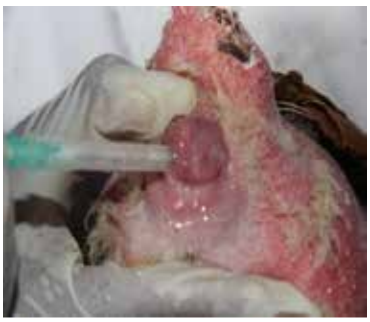


Photo credit: ILRI/Wondmeneh E.

9 Inbreeding

Inbreeding is the practice of mating two genetically related chickens. It is inevitable in long-term selection programs involving a closed population. Sometimes, it might even be necessary to mate inbred chicken to introduce certain characteristics in the flock that increase the frequency of favourable genes, or more rarely to expose recessive genes. The practice of breeding inbred lines causes inbreeding depression by increasing the number of recessive or deleterious genes being expressed. Reduction in fitness and productivity is called inbreeding depression. Breeders need to find a balance to optimize rates of genetic gain, while controlling the levels of inbreeding.

Breeding programs are prone to increased inbreeding due to the frequent use of artificial insemination, fast generation turnover, selective use of specific family lines and the tendency for a relatively small number of sire families to dominate within certain breeds. It is important to monitor and evaluate the level of inbreeding created in a population in every generation. This is calculated as inbreeding coefficient, which is defined as the probability of two alleles being identical by descent. Complete avoidance of inbreeding is impossible, and a balance should be created between the genetic superiority obtained from a specific chicken and the level of inbreeding that it creates in the future flock. The best solution to the inbreeding challenge is to measure its level between individuals and make recommendations based on this information.

Typical inbreeding percentages, assuming no previous inbreeding between any parents:

- **Father/daughter, mother/son, or brother/sister ⇢25%**
- **Grandfather/granddaughter or grandmother/grandson ⇢ 12.5%**
- **Half-brother/half-sister ⇢ 12.5%**
- **Uncle/niece or aunt/nephew ⇢ 12.5%**
- **Great-grandfather/great-granddaughter or great-grandmother/great-grandson ⇢ 6.25%**

10 Disseminating genetically superior chickens

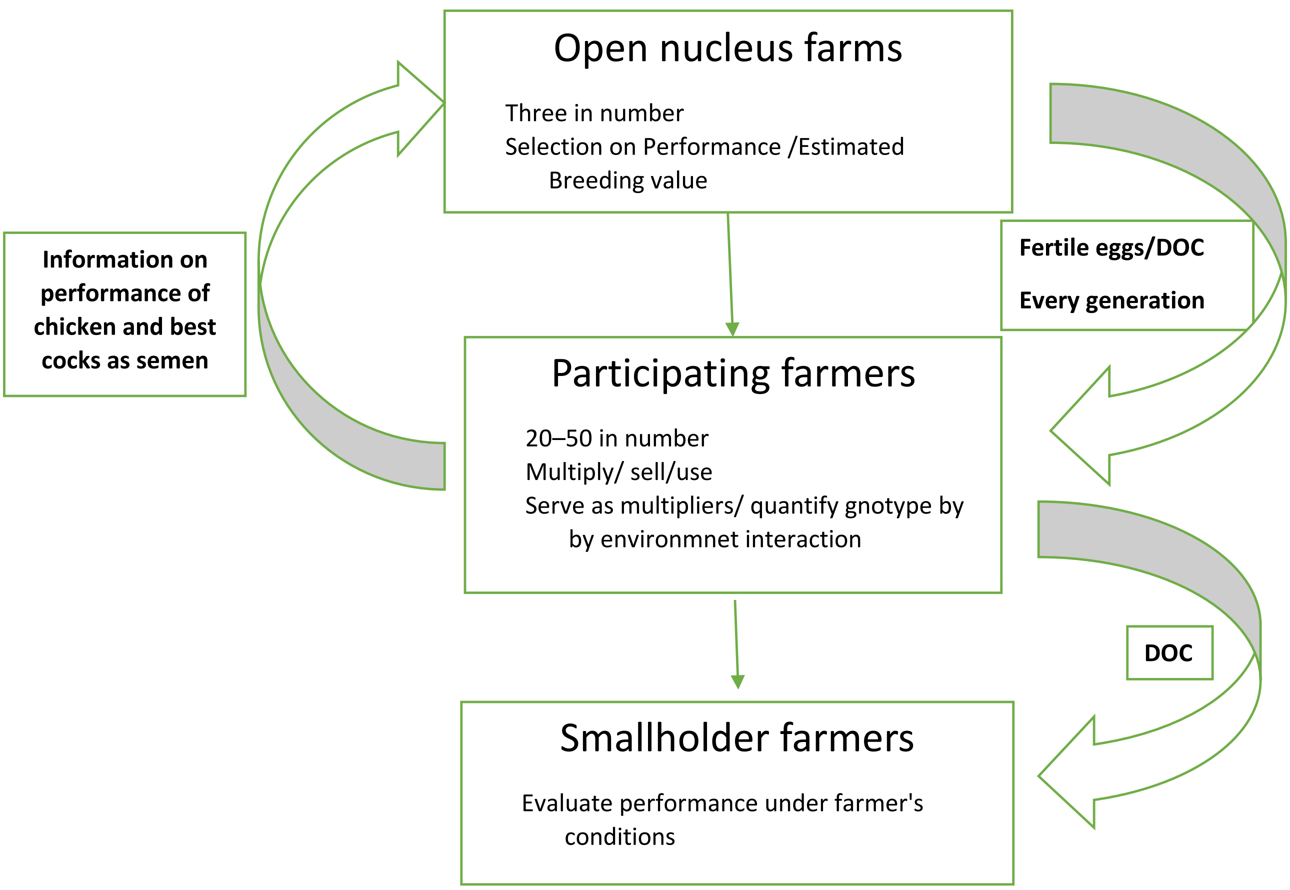
The overall objective of the breeding program is to deliver a genetically superior chicken to households. Flock improvement can be done continously in a nucleus flock then multiplied and disseminated to the end-users. Ideally, the multiplication is best done at a different farm, separate from the nucleus breeding flock. Keeping multiple flocks in a few places is also essential to protect against potential loss through disease outbreaks.

The government is best placed to focus on breeding programs involving indigenous chickens then transfer the improved nucleus flock to private companies, so public-private partnerships might be an ideal arrangement. The transfer of genetic gain from nucleus to industry can follow these two main paths:

- Direct transfer from the nucleus
- Transfer through multipliers

The means adopted depends on the conditions on the ground. The genetic gain should be significant enough to attract multipliers to take on the role of mass distribution.

Figure 10. Gene flow in a breeding program.



Typical inbreeding percentages, assuming no previous inbreeding between any parents:

- **Father/daughter, mother/son, or brother/sister ⇢ 25%**
- **Grandfather/granddaughter or grandmother/grandson ⇢ 12.5%**
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- **Uncle/niece or aunt/nephew ⇢ 12.5%**
- **Great-grandfather/great-granddaughter or great-grandmother/great-grandson ⇢ 6.25%**

11 Evaluating genetic gain and genetic trends of the breeding program

Genetic gain is the change realized in the average breeding value over at least one cycle selection for a particular trait or index of traits. The change in the breeding or genetic values of the population over many cycles or years is referred to as a genetic trend. Genetic trends are used to assess the effectiveness of breeding programs. In the indigenous chicken improvement program, the genetic gain and genetic trend should be evaluated after the program has been run for a few generations, ideally six generations. In the Horro chicken breeding program, an apparent gain and trend were observed after six generations of selection. Evaluating impacts of the selective breeding program can be seen as improvements realized in the breeding flock, in the field, or economic benefits.

11.1 Genetic gains realized in the breeding flock

This can be measured using a genetic trend plot, where estimated breeding values are plotted against the generations of improvement to evaluate whether a trend is increasing or decreasing. The other methodis carrying out a signature of selection using whole-genome analysis, which indicates the traits that were affected by the selective breeding program.

11.2 Changes in the field

The improved chicken can be compared both on-station (in a controlled environment) or in the field (on-farm conditions) against wild or unimproved chicken. The magnitude of the difference in the performance under similar management conditions reveals the actual improvement achieved in the program.

11.3 Economic benefits

The economic benefit of a breeding program can be evaluated by the percentage of genetic gain achieved and the corresponding profit gained by the program. Routine estimation of the rate of genetic gain is used to monitor its effectiveness. Genetic gain (ΔG) is the response to selection for additive genetic variance. It depends on additive genetic ($\sigma^2 A$) and phenotypic variances ($\sigma^2 P$), which are used to estimate a ratio known as narrow-sense heritability ($h^2 = \sigma^2 A/\sigma^2 P$), selection intensity (or the percentage of individuals selected and advanced to the next generation), parental control of males and females (c) and time.

12 Ownership of improved chicken breeds

Genetic materials in the indigenous chicken breed improvement programs are property of the government and specifically the smallholder farmers. The materials after improvement remain the property of the source. However, breeding companies need some form of legal or biological protection to be assured of revenues from genetic improvement and return on investments related to the development of genetically improved chicken strains.

13 Conclusion

Breeding programs need to be run for generations to achieve sustainable improvements. Besides, to ensure the chickens retain their adaptive capacity for on-farm conditions, the future generations should be performance-tested in less expensive management conditions that resemble the on-farm production environment. Second, the exact formulation of the breeding goal should be re-evaluated and may need to include additional traits that the farmers prefer. Such characteristics include the brown feather colour preferred by farmers in villages.

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