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AGE 406

POULTRY PRODUCTION EDUCATION

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Series 1: Principles and Systems of Poultry Production

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Introduction

Poultry production is Nigeria's most commercially developed livestock sub-sector, supplying the majority of domestically consumed animal protein through eggs and chicken meat. Understanding its scope, the systems used, the breeds available, and the structure of the industry is the essential foundation for effective poultry management.

This Series introduces the importance and history of Nigerian poultry production, compares the major production systems, describes indigenous and exotic breeds and commercial hybrids, and explains how the industry is organised and managed. These concepts underpin all practical management topics in Series 2 through 5.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** describe the importance and scope of poultry production in Nigeria (Linked to Part 1.1),
- **SLO 1.2** identify the major poultry species and state their key characteristics (Linked to Part 1.1),
- **SLO 1.3** describe the major poultry production systems and compare their advantages and limitations (Linked to Part 1.2),
- **SLO 1.4** describe Nigerian indigenous breeds, exotic breeds, and commercial hybrids (Linked to Part 1.3),
- **SLO 1.5** explain the principles of genetic selection used to produce commercial hybrids (Linked to Part 1.3),
- **SLO 1.6** describe the structure of the Nigerian poultry industry (Linked to Part 1.4), and
- **SLO 1.7** apply flock management principles and explain the importance of records and performance indices (Linked to Part 1.4).

1.1 Introduction to Poultry Production

1.1.1 Importance and scope of poultry production

Poultry provides eggs, meat, feathers, and manure. Eggs are the cheapest complete animal protein source in Nigeria; chicken meat is the second most consumed meat after beef. The Nigerian poultry sector comprises an estimated 180 million birds and contributes approximately 25 per cent of total agricultural GDP. It generates employment along the entire value chain: hatcheries, feed mills, farms, processors, and retailers.

Poultry manure is a valuable organic fertiliser for crop farming; feathers are processed into feather meal for animal feeds. The industry is relatively quick-returning: broilers reach slaughter weight in 5 to 6 weeks, and layers begin production at 18 to 20 weeks. These short production cycles make poultry attractive to entrepreneurial farmers seeking faster returns than ruminant livestock.

Fill in the blank: Nigeria has an estimated 180 million birds; the poultry sector contributes approximately _____ per cent of total agricultural GDP and is the fastest-returning livestock sub-sector.

1.1.2 Species of poultry and their characteristics

Chicken (Gallus gallus domesticus) is the most important poultry species globally and in Nigeria; it is raised for both eggs and meat. Turkey (Meleagris gallopavo) produces large carcasses and is popular for festive occasions; it has a longer production cycle than broiler chicken. Duck (Anas platyrhynchos) is hardy, water-loving, and produces eggs with higher yolk content than chicken eggs; it is important in riverine areas of southern Nigeria.

Guinea fowl (Numida meleagris) is well adapted to the Nigerian savanna; it is a good forager, disease-resistant, and valued for its distinctive flavour. Geese (Anser anser) are primarily grazers and are less common commercially. Pigeon (Columba livia) and quail (Coturnix coturnix japonica) are minor but growing species. Each species has distinct housing, feeding, incubation, and management requirements that the poultry manager must understand.

Fill in the blank: The _____ fowl is well adapted to the Nigerian savanna; it is a good forager, naturally disease-resistant, and produces meat valued for its distinctive gamey flavour.

Figure 1.1: Photographs of major poultry species kept in Nigeria

Figure 1.1: Photographs of major poultry species kept in Nigeria

1.1.3 History and development of poultry industry in Nigeria

Traditional poultry keeping in Nigeria dates back centuries; indigenous village chickens and guinea fowl were kept under extensive scavenging systems. Commercial poultry production began in the 1950s and 1960s with the introduction of exotic breeds and government farm settlements. The sector expanded rapidly in the 1970s and early 1980s, driven by oil wealth and government import restrictions that created a protected domestic market.

The structural adjustment programme of the mid-1980s caused severe disruption as feed ingredient costs rose sharply and credit became scarce. Recovery began in the 1990s and accelerated in the 2000s with private sector investment, particularly in integrated poultry companies (Chi Farms, Obasanjo Farms, Zartech). Today the sector is predominantly private and

semi-commercial, but the cost of feed (comprising 65 to 70 per cent of production cost) remains the dominant challenge.

Fill in the blank: Feed constitutes _____ to 70 per cent of poultry production cost in Nigeria; rising feed ingredient prices remain the most significant constraint on industry profitability.

Pilot questions 1.1

1. State six ways in which poultry production contributes to the Nigerian economy.
2. Name five poultry species and state one key characteristic of each.
3. Explain why broiler production has a shorter payback period than beef cattle production.
4. Describe the historical development of commercial poultry production in Nigeria.
5. Explain why feed cost is the dominant challenge in Nigerian poultry production.

1.2 Poultry Production Systems

1.2.1 Extensive and semi-intensive systems

In the extensive (village) system, birds scavenge freely for food (insects, seeds, kitchen scraps) around homesteads; no purpose-built housing, feeds, or veterinary inputs are provided. Production is very low but input cost is near zero. This system dominates in rural Nigeria and accounts for the majority of guinea fowl, local chickens, and duck production. Mortality is high due to predation, disease, and nutritional deficiency.

The semi-intensive system combines a simple shelter with a fenced yard, allowing some foraging while providing supplementary feed and water. Birds have better nutrition, growth rates, and survivability than in the extensive system. This system is common in peri-urban smallholder operations and suits small commercial layer or broiler units with 200 to 500 birds. It is a practical entry point for farmers transitioning from subsistence to commercial production.

Fill in the blank: The _____ system combines a simple shelter with a fenced yard; birds forage and receive supplementary feed; it suits smallholder commercial operations of 200 to 500 birds.

1.2.2 Intensive systems

The intensive system confines birds entirely within a purpose-built house; all feed, water, light, temperature, and health management are provided by the farmer. Stocking densities are high: 10 to 15 birds per m2 for broilers on litter; 450 cm2 per bird in battery cages for layers. Feed conversion is optimised, labour per bird is low, and management control is maximised. Almost all commercial Nigerian poultry operations use some form of intensive system.

Within intensive systems, two sub-types exist: floor (litter) systems house birds on wood shavings, rice husks, or sawdust bedding; cage systems house layers in wire cages (battery cages) that are stacked in tiers. Battery cages maximise space utilisation and facilitate individual egg collection but raise animal welfare concerns. Deep litter is the standard for broilers; battery cages are standard for commercial layers in Nigeria.

Fill in the blank: In battery cage systems for layers, each bird is allocated approximately _____ cm2 of floor space; cages maximise space use and egg collection efficiency but raise welfare concerns.

Figure 1.2: Photographs comparing extensive, semi-intensive, and intensive poultry production systems

Figure 1.2: Photographs comparing extensive, semi-intensive, and intensive poultry production systems

1.2.3 Organic and free-range systems

Free-range systems require birds to have meaningful access to outdoor areas; minimum outdoor space standards vary by certification body. Free-range eggs and meat command premium prices in urban Nigerian supermarkets and among health-conscious consumers. The system requires more land, results in higher feed wastage, and carries greater exposure to wild bird contact (a disease risk for avian influenza). Management skill and biosecurity are more demanding than in conventional intensive houses.

Organic poultry production requires birds to be raised on certified organic feeds without routine antibiotics, growth promoters, or synthetic pesticides. The Nigerian organic poultry market is small but growing, driven by urban middle-class demand. Organic certification from NAFDAC or international bodies is required for premium market access. Input costs are higher and yields

are lower than conventional systems, but premium pricing justifies the approach for well-connected niche marketers.

Fill in the blank: Organic poultry production requires certified organic feed and prohibits routine _____ and growth promoters; it targets a premium niche market and requires NAFDAC or international certification.

Pilot questions 1.2

1. Distinguish between the extensive and semi-intensive poultry production systems.
2. Describe the floor litter system and state its advantages over battery cages for broilers.
3. Explain what a battery cage system is and state two welfare concerns associated with it.
4. Describe the free-range poultry system and explain its main disease risk.
5. State three differences between organic and conventional intensive poultry production.

1.3 Poultry Breeds and Commercial Hybrids

1.3.1 Indigenous breeds in Nigeria

The Nigerian indigenous chicken (local breed) is a genetically diverse, unimproved landrace adapted to tropical conditions; it is characterised by small body size (1 to 1.5 kg live weight), low egg production (30 to 60 eggs per year), late sexual maturity (5 to 6 months), and exceptional hardiness under scavenging conditions. Its tolerance of Newcastle disease and heat stress makes it valuable in village systems where veterinary support is absent.

The Naked Neck (Frigate) local breed is notable for the absence of feathers on its neck, which improves heat dissipation; it is more heat-tolerant than feathered breeds and is found across the savanna zones. Other local breeds recognised in Nigeria include the Frizzle (with curled feathers), the Silkie, and various regional ecotypes. These indigenous breeds are genetically important resources and are the subject of conservation programmes at NAPRI and several Nigerian universities.

Fill in the blank: The Nigerian indigenous chicken has a live weight of 1 to 1.5 kg and produces only 30 to _____ eggs per year, but is exceptionally hardy and tolerates heat and Newcastle disease.

1.3.2 Exotic breeds and commercial hybrids

Exotic breeds introduced to Nigeria include: White Leghorn (primary egg-laying breed; 250 to 300 eggs per year; small body; nervous temperament); Rhode Island Red (dual-purpose; good egg production and moderate meat; docile; popular in semi-intensive systems); Plymouth Rock (dual-purpose; good forager); New Hampshire (meat emphasis; rapid growth). These pure breeds are rarely used in commercial production today; they have been replaced by commercial hybrids.

Commercial hybrid layers (e.g. Isa Brown, Hy-Line Brown, Lohmann Brown) are produced by crossing several pure lines to produce F1 birds with superior egg production (300 to 320 eggs per year), efficient feed conversion, and uniformity. Commercial broiler hybrids (e.g. Ross 308, Cobb 500, Arbor Acres) reach 2.0 to 2.5 kg live weight in 35 to 42 days with feed conversion ratios of 1.5 to 1.8. These hybrids dominate Nigerian commercial production.

Fill in the blank: Commercial broiler hybrids such as Ross 308 and Cobb 500 reach 2.0 to 2.5 kg live weight in _____ to 42 days with feed conversion ratios of 1.5 to 1.8.

Category	Body Weight	Egg Production	Maturity Age	Hardiness	Input Requirements
Indigenous	1–1.5 kg BW	30–60 eggs/year	5–6 months	Very hardy	Scavenges; low input
Pure Exotic	2–3 kg BW	150–250 eggs/year	18–22 weeks	Moderate hardiness	Requires proper housing and feeding
Commercial Hybrid	2–3.5 kg BW or 300–320 eggs/year	Layers mature at 16–18 weeks; broilers show rapid growth	High productivity	High input	Maximum performance under controlled environment

Box 1.1: Comparison of Nigerian indigenous chickens, pure exotic breeds, and commercial hybrids

1.3.3 Principles of genetic selection

Commercial hybrids are produced through systematic line breeding and controlled crossing by multinational breeding companies (Aviagen, Hendrix Genetics, Cobb-Vantress). The process involves: maintaining multiple pure inbred lines with specific traits (e.g. one line selected for growth rate, another for feed efficiency, another for meat yield); crossing specific lines to produce grandparent and parent stocks; and then crossing parent stocks to produce the commercial F1 hybrid sold to farmers.

Key selection criteria for layers: egg number, egg weight, shell quality, feed conversion per dozen eggs, livability, and temperament. For broilers: 42-day body weight, feed conversion ratio, breast meat yield, leg health (conformation), and livability. In Nigeria, only grandparent and parent stocks are imported; commercial chicks are hatched locally by primary breeders (Obasanjo Farms, Chi Farms, Zartech). Farmers buy commercial chicks from these hatcheries.

Fill in the blank: Commercial hybrids are produced by multinational companies such as Aviagen, Hendrix Genetics, and _____-Vantress, which maintain pure inbred lines and cross them in controlled programmes to maximise production traits.

Pilot questions 1.3

1. Describe the Nigerian indigenous chicken and explain its main advantage over exotic breeds under village conditions.
2. Name three exotic pure breeds used in Nigeria and state the primary use of each.
3. Describe a commercial hybrid layer and state its egg production potential.
4. Explain the difference between grandparent stock, parent stock, and commercial chicks.
5. State three selection criteria used in broiler breeding programmes.

1.4 Poultry Industry Structure and Management

1.4.1 Structure of the Nigerian poultry industry

The Nigerian poultry industry comprises three broad categories. Subsistence/village producers (the largest number of producers) keep 5 to 50 birds under extensive or semi-extensive conditions; they produce primarily for home consumption and local markets. Semi-commercial producers operate 500 to 10,000 birds; they use commercial feeds and hybrid stocks but may lack formal infrastructure. Commercial integrated producers (Chi Farms, Obasanjo Farms, Zartech, UAC Foods) maintain the full value chain from parent stock through hatchery, feed mill, grow-out farm, and processing plant.

Key support industries include: feed milling (over 300 registered feed mills nationally); hatcheries (day-old chick supply); veterinary pharmaceutical distributors; equipment suppliers; and cold chain and processing companies. Trade associations such as the Poultry Association of Nigeria (PAN) and the Hatchery Association of Nigeria (HAN) coordinate advocacy, training, and sector data collection. NAFDAC and the Federal Ministry of Agriculture and Food Security regulate product safety and disease control.

Fill in the blank: The Poultry Association of _____ (PAN) is the primary industry advocacy and coordination body; it represents farmers, hatcheries, feed millers, and equipment suppliers across the sector.

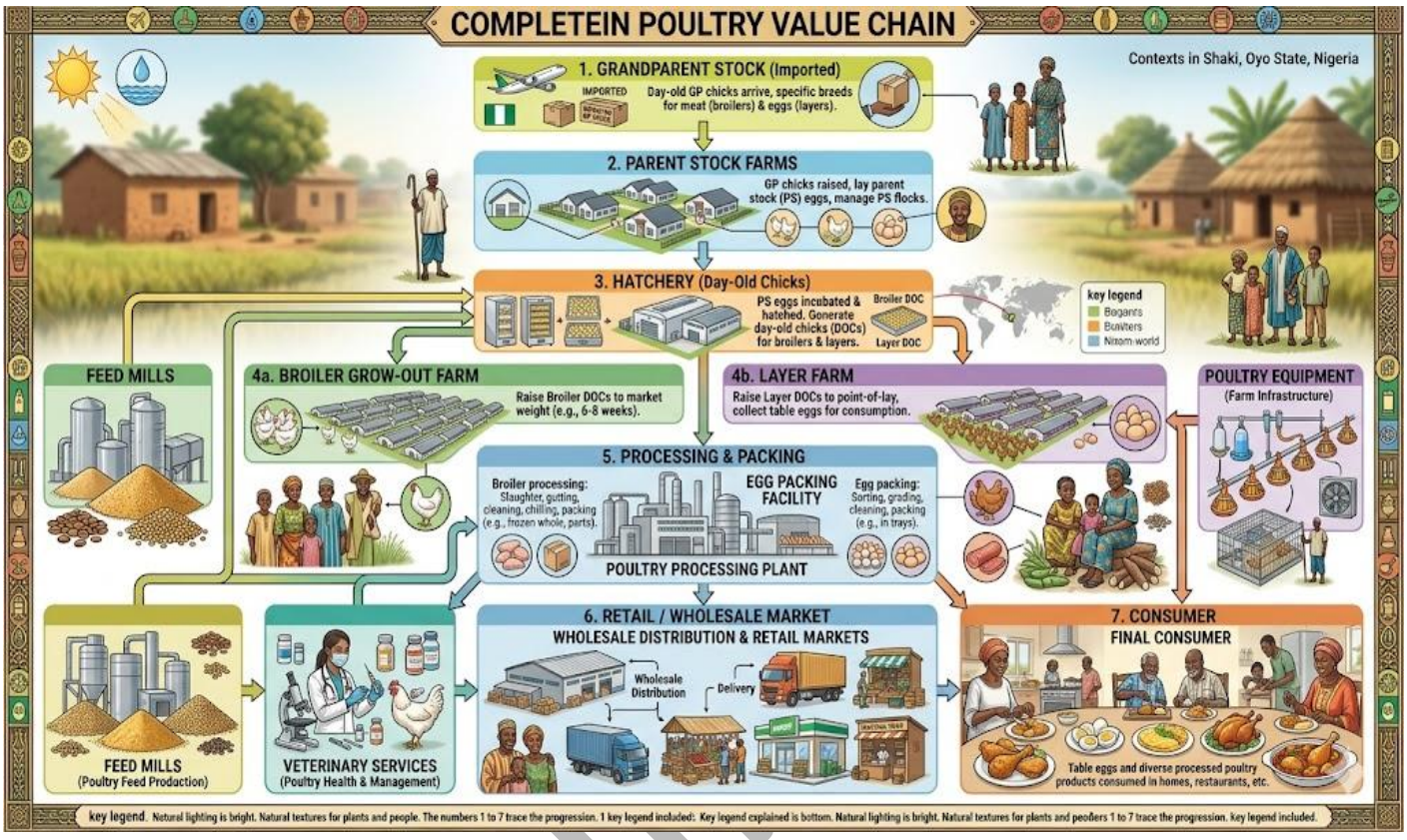

Figure 1.3: Diagram of the Nigerian poultry value chain from grandparent stock to consumer

1.4.2 Flock management principles

All-in-all-out (AIAO) management is the principle of placing all birds in a house at the same time and removing all birds at the same time before thoroughly cleaning and disinfecting the house before the next batch. AIAO breaks the cycle of pathogen accumulation that occurs in continuous stocking systems. It is the standard practice for broiler production and is strongly recommended for turkey and broiler breeder management.

Other core flock management principles: biosecurity (preventing disease entry; controlling visitor access; disinfection protocols); flock uniformity monitoring (weekly weighing of a 5 per cent sample to ensure uniform growth; CV below 10 per cent indicates good flock uniformity); feed and water management (ad libitum feeding for broilers; controlled feeding for layers; water consumption is 1.5 to 2 times feed consumption by weight); and mortality recording (daily mortality count and recording; mortality above 0.5 per cent per day triggers investigation).

Fill in the blank: All-in-all-out (_____) management places all birds in a house together and removes all birds together before clean-out and disinfection; it prevents pathogen accumulation between batches.

1.4.3 Record-keeping and performance indices

Accurate records are essential for detecting problems early, calculating production costs, and making management decisions. Key records every poultry farm should maintain: daily mortality count (by house and species); daily feed consumption (kg per house per day); weekly body weight sample (broilers); weekly egg production count (layers); cumulative feed conversion ratio (FCR = total feed consumed / total weight gain or total egg weight); and medication and vaccination records.

Key performance indices: Feed Conversion Ratio (FCR: broiler target 1.5-1.8; lower is better); Hen Day Production (HDP: eggs produced per hen present each day, expressed as a percentage; target 85-92% for commercial layers at peak); Livability (percentage of birds alive at end of production period; target >96%); European Production Efficiency Factor (EPEF = livability% x body weight (kg) / (FCR x age in days) x 100; higher is better for broilers).

Fill in the blank: Hen Day Production (HDP) is the number of eggs produced per hen _____ each day expressed as a percentage; the target for commercial layers at peak is 85 to 92 per cent.

Production Type	Key Parameters	Benchmark Values
Broilers (Ross 308, 42-day cycle)	Target body weight	2.2–2.5 kg
	Feed Conversion Ratio (FCR)	1.55–1.75
	Livability	>96%
	European Production Efficiency Factor (EPEF)	>320
Layers (Isa Brown, 72-week cycle)	Age at first egg	18–19 weeks
	Peak Hen-Day Production (HDP)	92–95%
	Average HDP over 72 weeks	80–85%

	Total eggs per hen housed	300–315
	Average egg weight	62–65 g
	FCR per dozen eggs	1.3–1.5 kg feed/dozen
	Livability to 72 weeks	>95%

Box 1.2: Standard performance benchmarks for commercial broiler and layer production in Nigeria

Pilot questions 1.4

1. Describe the three categories of Nigerian poultry producers and distinguish between them.
2. Explain the all-in-all-out system and state why it is preferred over continuous stocking.
3. List six records that every poultry farm should maintain and explain the purpose of each.
4. Define FCR, HDP, and EPEF and state the target value for each in commercial production.
5. Explain what flock uniformity is and describe how it is measured.

Series Summary

This Series introduced the principles and systems of Nigerian poultry production. Poultry provides eggs, meat, feathers, and manure; the sector has approximately 180 million birds and contributes 25% of agricultural GDP. Five major species (chicken, turkey, duck, guinea fowl, quail) were described. Production systems range from extensive (scavenging, near-zero input) through semi-intensive to intensive (floor litter and battery cage), with free-range and organic systems addressing niche premium markets.

Indigenous breeds (1-1.5 kg; 30-60 eggs/year; heat-tolerant; hardy) were contrasted with exotic breeds and commercial hybrids (300-320 eggs/year for layers; 2.2-2.5 kg in 42 days for broilers). Commercial hybrids are produced by multinational companies through line crossing. The Nigerian poultry industry structure (subsistence, semi-commercial, commercial integrated) and

the key support industries were described. Flock management principles (AIAO, biosecurity, uniformity monitoring) and performance indices (FCR, HDP, livability, EPEF) completed the Series. By completing this Series, you should achieve all seven SLOs (1.1 to 1.7).

Glossary of Terms

- **All-in-all-out (AIAO):** placing and removing all birds from a house simultaneously, followed by thorough clean-out and disinfection before the next batch; prevents pathogen accumulation.
- **Battery cage:** a wire cage system in which laying hens are housed individually or in small groups in stacked tiers; maximises space and egg collection efficiency.
- **Broiler:** a chicken raised specifically for meat production; modern commercial hybrids reach 2.0-2.5 kg in 35-42 days.
- **Commercial hybrid:** a first-generation (F1) cross of multiple pure inbred lines, producing birds with maximum uniformity and production performance; produced by multinational breeding companies.
- **Day-old chick (DOC):** a newly hatched chick, typically 24-72 hours old, purchased from a hatchery; the entry point for most Nigerian commercial poultry farms.
- **Deep litter:** a floor management system using wood shavings, rice husks, or sawdust as bedding material on which broilers are raised; the litter is managed throughout the production cycle.
- **EPEF (European Production Efficiency Factor):** a composite broiler performance index: (livability% x BW kg) / (FCR x age in days) x 100; higher is better.
- **Extensive system:** a low-input poultry system in which birds scavenge freely with no purpose-built housing or provided feed; typical of village production.
- **FCR (Feed Conversion Ratio):** total feed consumed divided by total weight gain (or egg weight); lower FCR indicates greater feed efficiency.
- **Free-range system:** a system providing birds with meaningful access to outdoor areas; commands price premiums but requires more land and biosecurity management.

- **Grandparent stock:** the parent generation whose controlled crossing produces parent stock; grandparents are imported to Nigeria by primary breeders.
- **HDP (Hen Day Production):** eggs produced per hen present per day, expressed as a percentage; target 85-92% at commercial layer peak production.
- **Indigenous breed:** a locally adapted, unimproved landrace; in Nigerian poultry, the local chicken is characterised by hardiness, small size, and low egg production.
- **Intensive system:** a high-input poultry system with complete confinement; feed, water, light, and health are fully managed; used by all commercial Nigerian operations.
- **Layer:** a hen raised specifically for egg production; commercial hybrid layers produce 300-320 eggs per year.
- **Livability:** the percentage of birds surviving to the end of the production period; target >96% for commercial broilers and >95% for layers.
- **Organic poultry:** birds raised on certified organic feeds without routine antibiotics or growth promoters; requires NAFDAC or international certification.
- **Parent stock:** the generation produced from grandparent crossing; parent stock flocks produce the commercial fertilised eggs that are hatched into commercial day-old chicks.
- **Semi-intensive system:** a system combining simple shelter with a fenced yard; birds receive supplementary feed and have limited outdoor access.

Concept Check Questions [Series 1]

Objective Questions

1. Nigeria has approximately 180 million birds; the poultry sector contributes approximately _____ per cent of agricultural GDP. (Linked to SLO 1.1)
2. The _____ fowl is well adapted to the Nigerian savanna; it is hardy, a good forager, and disease-resistant. (Linked to SLO 1.2)
3. In battery cage systems, each layer is allocated approximately _____ cm2 of floor space. (Linked to SLO 1.3)

4. Commercial broiler hybrids reach 2.0 to 2.5 kg in _____ to 42 days with FCR of 1.5 to 1.8. (Linked to SLO 1.4)
5. All-in-all-out (AIAO) management places and removes all birds simultaneously, then clean-out is carried out before the next _____. (Linked to SLO 1.7)

Short-Answer Questions

6. State five contributions of poultry production to the Nigerian economy. (Linked to SLO 1.1)
7. Compare the extensive and intensive production systems in terms of inputs, outputs, and suitability. (Linked to SLO 1.3)
8. Distinguish between the Nigerian indigenous chicken and a commercial hybrid layer. (Linked to SLO 1.4)
9. Explain what FCR and HDP are and state the target for each in commercial production. (Linked to SLO 1.7)
10. Explain the all-in-all-out system and state its main advantage. (Linked to SLO 1.7)

Long-Answer Questions

11. Describe the scope, importance, and historical development of poultry production in Nigeria, and compare the major production systems. (Linked to SLOs 1.1, 1.2, 1.3)
12. Describe the breeds and commercial hybrids used in Nigerian poultry production and explain the principles of genetic selection. (Linked to SLOs 1.4, 1.5)
13. Describe the structure of the Nigerian poultry industry, flock management principles, and the key performance indices. (Linked to SLOs 1.6, 1.7)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. 25.

2. Guinea.
3. 450.
4. 35.
5. Batch.

Short-Answer Questions

6. Provides affordable animal protein (eggs, meat); generates rural and urban employment; supplies organic manure for crop farming; produces feathers for feather meal; generates foreign exchange through hide and processed product exports; contributes 25% of agricultural GDP.
7. Extensive: zero or minimal inputs; birds scavenge freely; near-zero feed cost; high mortality; very low output; suits village subsistence producers. Intensive: high inputs (commercial feed, housing, health management); complete confinement; very high output; low mortality; standard for commercial Nigerian farms. Intensive is only viable with capital investment; extensive is the default where capital is absent.
8. Indigenous: 1-1.5 kg BW; 30-60 eggs/year; 5-6 months to maturity; very hardy; scavenges; survives without commercial feed. Commercial hybrid layer: 1.5-2.0 kg BW; 300-320 eggs/year; matures at 18-19 weeks; requires controlled housing, commercial feed, and vaccination programme; not adapted to scavenging conditions.
9. FCR = total feed consumed / total weight gain; target 1.5-1.8 for broilers (lower is better). HDP = eggs produced per hen present per day as a percentage; target 85-92% at commercial layer peak production.
10. AIAO places all birds in a house at the same time and removes all birds at the same time; the house is then completely cleaned and disinfected before the next batch. Main advantage: breaks the pathogen accumulation cycle, reducing disease pressure on each successive batch.

Long-Answer Questions

11. Scope and importance: 180 million birds; 25% agricultural GDP; supplies majority of domestic animal protein; generates employment in hatcheries, feed mills, farms, and processing; manure for crop farming. Species: chicken (eggs and meat), turkey (festive large carcass), duck (riverine

areas), guinea fowl (savanna forager), quail (eggs, growing niche). History: traditional village keeping pre-colonial; commercial expansion 1950s-60s with exotic breeds and government settlements; rapid growth 1970s-80s (oil wealth, import restrictions); disruption from 1986 SAP (feed costs, scarce credit); recovery 1990s-2000s (private sector: Chi Farms, Obasanjo, Zartech); feed at 65-70% production cost remains the dominant constraint. Production systems: extensive (scavenging; zero input; high mortality; village); semi-intensive (shelter + fenced yard; supplementary feed; 200-500 birds; peri-urban smallholder); intensive floor litter (full confinement; wood shavings bedding; 10-15 birds/m2; standard for broilers); battery cage (wire cages, 450 cm2/bird; standard for commercial layers); free-range (outdoor access; premium prices; disease risk from wild birds); organic (no antibiotics; certified organic feed; NAFDAC certification).

12. Indigenous breeds: local chicken (1-1.5 kg; 30-60 eggs/year; 5-6 months maturity; hardy; heat-tolerant; tolerates Newcastle disease); Naked Neck (improved heat dissipation; featherless neck; savanna-adapted); conservation at NAPRI and universities. Exotic pure breeds: White Leghorn (250-300 eggs/year; small body; nervous); Rhode Island Red (dual-purpose; docile); Plymouth Rock (dual-purpose; forager); New Hampshire (meat emphasis). Commercial hybrids: layer hybrids (Isa Brown, Hy-Line Brown, Lohmann Brown; 300-320 eggs/year; 18-19 weeks to first egg; efficient FCR per dozen); broiler hybrids (Ross 308, Cobb 500, Arbor Acres; 2.2-2.5 kg in 35-42 days; FCR 1.5-1.8). Genetic selection principles: multinational companies (Aviagen, Hendrix Genetics, Cobb-Vantress) maintain pure inbred lines; lines selected for specific traits (growth, feed efficiency, egg number, shell quality, breast yield, leg health, livability); controlled crossing produces grandparent stock, then parent stock, then F1 commercial chicks; only grandparent and parent stock imported to Nigeria; commercial chicks hatched locally by Obasanjo Farms, Chi Farms, Zartech.
13. Industry structure: subsistence/village (5-50 birds; extensive; home consumption; majority of producers by number); semi-commercial (500-10,000 birds; commercial feeds, hybrid stock, basic infrastructure); commercial integrated (Chi Farms, Obasanjo, Zartech; full value chain from parent stock through hatchery, feed mill, grow-out, processing). Support industries: 300+ feed mills; hatcheries supplying day-old chicks; veterinary pharmaceutical distributors; cold chain and processing companies. Associations: PAN (advocacy and coordination); HAN (hatchery sector). Regulation: NAFDAC and FMAFS. Flock management principles: AIAO (all birds in/out together; house cleaned and disinfected between batches; prevents pathogen accumulation); biosecurity (controlled access, disinfection, quarantine); flock uniformity (weekly 5% sample weighing; CV <10%); ADLIB feeding for broilers; controlled feeding for layers; water = 1.5-2x

feed consumption; daily mortality recording (>0.5%/day triggers investigation). Performance indices: FCR (feed/gain; target 1.55-1.75 for broilers); HDP (eggs/hen present/day %; target 85-92% peak); livability (% surviving; target >96% broilers, >95% layers); EPEF ((livability% x BW) / (FCR x age) x 100; target >320 for broilers).

Answers to Pilot Questions [Series 1]

Part 1.1

1. Six contributions: supplies eggs (cheapest animal protein source in Nigeria); supplies chicken meat (second most consumed meat after beef); generates employment in hatcheries, feed mills, farms, processing, and retail; provides manure as organic fertiliser for crop farming; feathers processed into feather meal for animal feeds; contributes approximately 25% of agricultural GDP.
2. Chicken (most important globally and in Nigeria; raised for eggs and meat); turkey (large carcass; festive occasions; longer production cycle); duck (hardy; water-loving; higher yolk eggs; riverine southern Nigeria); guinea fowl (savanna-adapted; good forager; disease-resistant; distinctive flavour); quail (small eggs; growing niche market).
3. Broilers reach 2.0-2.5 kg slaughter weight in only 35-42 days; the entire production cycle from placement to sale takes under 6 weeks. Beef cattle require 18-36 months to reach slaughter weight. The short production cycle means broiler capital turns over 6-8 times per year versus once every 1-3 years for beef cattle, yielding faster cash flow and lower tied-up capital per production unit.
4. Traditional village keeping dates centuries before colonial Nigeria. Commercial production began in the 1950s-60s with government farm settlements and exotic breed importation. Rapid expansion occurred in the 1970s-80s under oil wealth and import restrictions. The 1986 SAP caused severe disruption: feed prices rose sharply, credit became scarce, and many farms collapsed. Recovery from the 1990s was driven by private sector investment, particularly integrated companies (Chi Farms, Obasanjo Farms, Zartech) that built self-contained value chains.
5. Feed constitutes 65-70% of total poultry production cost in Nigeria. The main feed ingredients (maize and soyabean meal) are also major food crops competing with human consumption and subject to seasonal price volatility, import policy changes, and supply shortfalls. When maize

prices rise by 20%, production cost rises by approximately 10-14%, squeezing or eliminating profit margins in commercial operations with fixed sale prices.

Part 1.2

1. Extensive: birds scavenge freely; no purpose-built housing or provided feed; zero or minimal input cost; high mortality from predation, disease, and malnutrition; very low productivity; typical of rural village producers. Semi-intensive: simple shelter with fenced yard; supplementary feed and water provided; moderate inputs; better nutrition, growth, and survivability than extensive; suits peri-urban smallholders of 200-500 birds; entry-level commercial system.
2. Floor litter system houses broilers on a 5-10 cm deep layer of wood shavings, rice husks, or sawdust on a concrete or earth floor; birds move freely within the house; feeding and watering equipment is distributed throughout the floor area; stocking density is 10-15 birds/m2. Advantages over battery cages for broilers: allows natural movement, feeding, and social behaviour; litter bacteria break down faeces, reducing ammonia; no individual confinement; lower equipment capital cost; standard welfare requirement for broiler production.
3. Battery cages are wire-mesh cages stacked in multiple tiers in which laying hens are permanently housed; each hen has approximately 450 cm2 of floor space; sloped wire floors allow eggs to roll to a collection trough at the front of the cage. Two welfare concerns: (1) physical restriction prevents natural behaviours (wing stretching, dustbathing, perching, nesting) causing chronic behavioural frustration; (2) wire floors cause foot pad injury and leg disorders with no soft substrate available.
4. Free-range system provides birds with access to outdoor areas in addition to a conventional poultry house; EU minimum standard is 4 m2 outdoor space per bird; Nigerian premium market equivalent requires similar outdoor access. Birds forage on grass and insects in addition to provided feed. Main disease risk: contact with wild birds (migratory waterfowl and wild birds are reservoirs for highly pathogenic avian influenza H5N1); outdoor access allows virus transmission through wild bird faeces on pasture or in shared water sources.
5. Three differences: (1) organic requires certified organic feed free from synthetic pesticides; conventional uses commercial compound feeds with permitted additives; (2) organic prohibits routine preventive antibiotic use; conventional uses prophylactic antibiotics in some management protocols; (3) organic requires NAFDAC or equivalent certification for every production input

and finished product; conventional requires only basic NAFDAC product registration; organic commands 50-150% price premium over conventional in Nigerian urban supermarkets.

Part 1.3

1. Nigerian indigenous chicken: small body (1-1.5 kg); low egg production (30-60/year); late maturing (5-6 months); unimproved landrace adapted to tropical conditions. Main advantage under village conditions: exceptional hardiness; tolerates heat, poor nutrition, Newcastle disease, and other endemic pathogens without veterinary support; survives on minimal scavenged feed; has some natural resistance to local disease strains built over generations of natural selection.
2. White Leghorn (primary egg laying; 250-300 eggs/year); Rhode Island Red (dual-purpose; eggs and moderate meat; docile; suitable for semi-intensive); Plymouth Rock (dual-purpose; good forager; hardier than Leghorn).
3. A commercial hybrid layer is a first-generation (F1) cross of multiple pure inbred lines, produced by multinational companies such as Hendrix Genetics (Isa Brown, Lohmann Brown) and Hy-Line International (Hy-Line Brown). Egg production potential: 300-320 eggs per hen housed over a 72-week laying cycle; age at first egg 18-19 weeks; peak HDP 92-95%; average egg weight 62-65 g.
4. Grandparent stock: the first imported generation; crossing grandparents produces parent stock. Parent stock: raised on specialised breeding farms; their fertile eggs are hatched to produce commercial day-old chicks. Commercial chicks: the F1 generation sold to grow-out farmers; they are the end product of the breeding pyramid and cannot be used as parents (their offspring would be genetically segregated and non-uniform).
5. Three broiler selection criteria: (1) 42-day body weight (heavier birds reach market weight faster, reducing fixed cost per kg); (2) feed conversion ratio (lower FCR means less feed per kg of gain, directly reducing the dominant production cost); (3) breast meat yield as a percentage of carcass weight (the highest-value cut; breeds differ significantly in breast development).

Part 1.4

1. Three categories: subsistence/village (5-50 birds; extensive or semi-extensive; local breeds; primarily home consumption; no commercial infrastructure; majority of producers by number but minority of output by volume); semi-commercial (500-10,000 birds; commercial hybrid chicks and compound feeds; basic housing; produces for local urban markets; majority of Nigerian commercial birds); commercial integrated (>10,000 birds; full value chain from parent stock through hatchery, feed mill, grow-out farm, processing, and marketing; examples: Chi Farms, Obasanjo Farms, Zartech, UAC Foods).
2. AIAO places all birds in a house simultaneously (same age, same source) and removes all birds simultaneously at the end of the production cycle; the empty house is completely depopulated, cleaned, disinfected (washing, lime or formalin fumigation), and rested for a minimum of 2 weeks before the next batch enters. Preferred over continuous stocking because: in continuous systems, new birds are constantly exposed to pathogens shed by older birds; disease challenges intensify over successive crops; AIAO eliminates this age-structured pathogen accumulation by ensuring each batch enters a clean, pathogen-minimised environment.
3. Six records and purposes: daily mortality count (detect disease outbreaks early; track livability); daily feed consumption per house (monitor intake against targets; detect appetite loss indicating disease or heat stress); weekly body weight sample — 5% of flock (track growth against breed standard; identify uniformity problems); weekly egg production count (calculate HDP; detect production drops); cumulative FCR (measure feed efficiency; benchmark against targets); medication and vaccination records (compliance documentation; trace disease events; regulatory requirement).
4. FCR (Feed Conversion Ratio) = total feed consumed (kg) / total weight gain (kg); target 1.55-1.75 for commercial broilers; lower FCR means less feed per kg of meat, directly reducing the largest cost component. HDP (Hen Day Production) = (eggs produced per day / hens present per day) x 100%; target 85-92% at commercial layer peak; measures the proportion of hens laying each day. EPEF (European Production Efficiency Factor) = (livability% x BW kg) / (FCR x age in days) x 100; target >320 for commercial broilers; integrates growth, feed efficiency, livability, and age into a single index.
5. Flock uniformity measures how evenly birds in a house are growing; it is quantified as the Coefficient of Variation (CV) of body weight from a weekly 5% sample weigh: CV = (standard deviation / mean body weight) x 100. A CV below 10% indicates good uniformity; above 15% indicates significant variation requiring investigation (e.g. feeder or drinker competition, disease in part of the flock, mycotoxin in feed). Poor uniformity means some birds are over-conditioned while others are stunted, reducing average performance and market value.

References and Attributions [Series 1]

Textual References (Books and External Sources)

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Figures, Plates, Tables, and Boxes

- Figure 1.1: Major poultry species in Nigeria Attribution: AI generated. Suggested OER search string: "poultry species Nigeria chicken turkey duck guinea fowl quail photographs OER".
- Figure 1.2: Comparison of poultry production systems Attribution: AI generated. Suggested OER search string: "poultry production systems extensive semi-intensive intensive Nigeria photographs comparison OER".
- Box 1.1: Comparison of indigenous, exotic, and hybrid poultry Attribution: AI generated. Suggested OER search string: "comparison indigenous exotic hybrid poultry breeds Nigeria OER box".
- Figure 1.3: Nigerian poultry value chain diagram Attribution: AI generated. Suggested OER search string: "Nigeria poultry value chain grandparent hatchery broiler processing retail OER diagram".
- Box 1.2: Production benchmarks for broilers and layers Attribution: AI generated. Suggested OER search string: "poultry production benchmarks broiler layer FCR HDP Nigeria OER box".

Course code: AGE 406

Course title: Poultry Production Education

Series 2: Housing, Equipment, and Hatchery Management

- **Part 2.1: Poultry House Design and Construction**
  - Sub Part 2.1.1: Principles of poultry house design
  - Sub Part 2.1.2: Types of poultry houses
  - Sub Part 2.1.3: Site selection and house orientation
- **Part 2.2: Poultry Equipment**
  - Sub Part 2.2.1: Feeding and watering equipment
  - Sub Part 2.2.2: Heating, lighting, and ventilation equipment
  - Sub Part 2.2.3: Handling and sanitation equipment
- **Part 2.3: The Hatching Egg and Incubation**
  - Sub Part 2.3.1: Selection and handling of hatching eggs
  - Sub Part 2.3.2: Principles and requirements of incubation
  - Sub Part 2.3.3: Types of incubators
- **Part 2.4: Hatchery Management**
  - Sub Part 2.4.1: Hatchery layout and biosecurity
  - Sub Part 2.4.2: Incubation management and candling
  - Sub Part 2.4.3: Hatching, chick processing, and hatchery records

Introduction

Appropriate housing and equipment are prerequisites for efficient poultry production; a poorly designed house or inadequate equipment undermines all other management inputs. Equally, the hatchery is the entry point of every commercial flock: the quality of incubation management determines chick quality, which directly affects the performance of every subsequent production stage.

This Series covers the principles of poultry house design and construction, the major equipment items for feeding, watering, heating, lighting, and ventilation, and the full hatchery management cycle from hatching egg selection through incubation and chick processing. These topics apply to all poultry species covered in the course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** describe the principles of poultry house design and the types of houses used for commercial production (Linked to Part 2.1),
- **SLO 2.2** explain the criteria for site selection and house orientation in the Nigerian climate (Linked to Part 2.1),
- **SLO 2.3** describe the feeding, watering, heating, lighting, and ventilation equipment used in poultry production (Linked to Part 2.2),
- **SLO 2.4** describe the selection, grading, and storage of hatching eggs (Linked to Part 2.3),
- **SLO 2.5** explain the principles and requirements of artificial incubation (Linked to Part 2.3),
- **SLO 2.6** describe the types of incubators and distinguish between setters and hatchers (Linked to Part 2.3), and
- **SLO 2.7** describe hatchery layout, incubation management, candling, hatching, chick processing, and hatchery record-keeping (Linked to Part 2.4).

2.1 Poultry House Design and Construction

2.1.1 Principles of poultry house design

A good poultry house must: provide protection from predators, rain, and direct sun; maintain optimal temperature (18 to 24 degrees Celsius for adult birds; 33 to 35 degrees for day-old chicks); ensure adequate ventilation to remove heat, moisture, ammonia, and CO2; be easy to clean and disinfect; and be economical to construct and maintain. In Nigeria's hot tropical climate, ventilation and shade are the dominant design priorities.

Key design parameters: minimum roof height of 3 m at the eave for natural ventilation; wide overhang (0.6 to 1 m) to shade sidewalls from direct sun; open or curtain-sided walls to allow cross-ventilation; east-west orientation of the long axis to minimise direct solar radiation on the sidewalls; solid concrete or compacted earth floor sloped 1 to 2% to a central or perimeter drain for easy washing.

Fill in the blank: The long axis of a poultry house should be oriented _____-west to minimise direct solar radiation on the sidewalls; wide roof overhangs shade the walls and reduce internal temperature.

2.1.2 Types of poultry houses

Open-sided (tropical) houses use wire mesh or curtain-sided walls to maximise natural ventilation; they are the most common type in Nigeria and suit the year-round warm climate. Closed (controlled environment) houses are fully enclosed with mechanical ventilation (fans) and evaporative cooling; they are more expensive but allow precise environmental control, making them suitable for high-density broiler production in hot conditions. Curtain-sided houses combine elements of both: curtains can be raised or lowered depending on weather.

Specific-purpose house types: brooder house (small, heavily insulated to maintain 33 to 35 degrees Celsius for chicks in the first 2 to 3 weeks); grow-out house (standard house for broilers from 2 weeks to slaughter); layer house with battery cage installation; breeder house with nest

boxes for egg collection; and pullet rearing house. Each type has specific space, equipment, lighting, and management requirements.

Fill in the blank: Open-sided (tropical) houses with wire mesh or _____-sided walls are the most common type in Nigeria; they rely on natural cross-ventilation and are well-suited to the year-round warm climate.

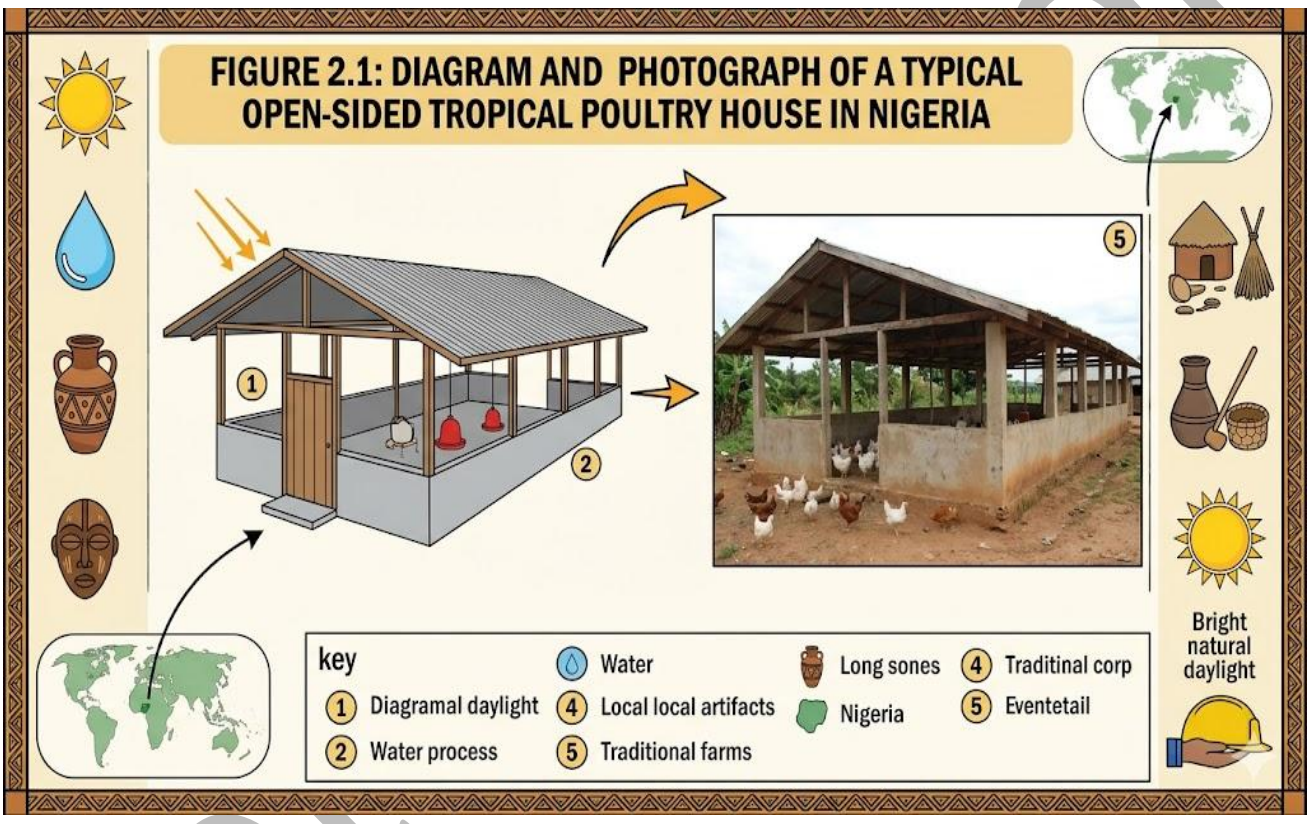

Figure 2.1: Diagram and photograph of a typical open-sided tropical poultry house in Nigeria

2.1.3 Site selection and house orientation

Site selection criteria: elevated and well-drained land (prevents flooding and dampness, which predispose to respiratory disease and Marek's disease); prevailing breeze direction (site houses so prevailing winds blow through the house lengthwise to maximise ventilation); distance from other farms (minimum 500 m biosecurity buffer to reduce airborne disease transmission); access to reliable water supply; proximity to roads for feed delivery and product transport.

House spacing: where multiple houses are on the same farm, minimum spacing should be 20 to 25 m between houses (equal to the width of one house) to allow light, air movement, and independent biosecurity management of each house. Houses should be staggered (not aligned) so that the exhaust air from one house does not blow directly into the inlet of the next. Access roads, feed storage, and waste disposal areas must be planned to prevent cross-contamination between houses.

Fill in the blank: Minimum spacing between poultry houses on the same farm is _____ to 25 m; houses should be staggered so that exhaust air from one house does not enter the inlet of the next.

Pilot questions 2.1

1. State five principles of good poultry house design.
2. Distinguish between an open-sided house and a closed environment house for broiler production.
3. Explain why a poultry house should be oriented with its long axis east-west.
4. State five criteria for selecting a site for a commercial poultry farm.
5. Explain why correct spacing between houses on a farm is important.

2.2 Poultry Equipment

2.2.1 Feeding and watering equipment

Feeding equipment: tubular feeders (hanging tube feeders suspended from the roof; self-filling from a feed hopper; standard for broilers and pullets on floor systems); trough feeders (linear troughs along the house wall; used for chicks and for feed distribution in battery cages); pan feeders (circular pans on automated feed lines; most common in modern commercial broiler houses). Each pan or tubular feeder accommodates approximately 35 to 50 chicks; space must be adequate to prevent competition.

Watering equipment: bell drinkers (hanging bell-shaped open drinkers filled by a float valve; inexpensive; common for chicks and small flocks); nipple drinkers (birds peck a metal nipple to release a drop of water; standard in commercial broiler and layer houses; reduces water wastage and contamination; requires adequate water pressure of 15 to 25 psi). Water consumption is 1.5 to 2 times feed consumption; water must be clean, cool, and always available. Drinker height must be adjusted as birds grow.

Fill in the blank: Nipple drinkers require a water pressure of _____ to 25 psi; they are standard in commercial broiler and layer houses because they reduce water wastage and contamination compared with open bell drinkers.

2.2.2 Heating, lighting, and ventilation equipment

Brooders provide supplementary heat for chicks in the first 2 to 3 weeks when thermoregulation is insufficient. Types: gas brooder (propane or butane-fuelled radiant heater; most common; provides 2,500 kcal/hour; covers approximately 500 chicks per brooder); electric brooder (infrared bulb; suitable for small flocks and power-reliable locations); hover brooder (a dome-shaped heat reflector suspended above chicks). Brooding temperature: 33 to 35 degrees Celsius at chick level on day 1, reduced by 2 to 3 degrees per week.

Lighting: incandescent or LED lights provide supplementary photoperiod control. Layers require increasing daylength to stimulate and maintain egg production: 8 hours in the starter phase increasing to 16 hours by the time of production. Broilers receive near-continuous light (23 hours light: 1 hour dark) to maximise feeding time and growth. Ventilation: minimum ventilation removes moisture and ammonia; tunnel ventilation (all fans at one end, air inlets at the other) is standard in closed houses; natural ventilation through open sidewalls is standard in tropical open houses.

Fill in the blank: Laying hens require a daylength of at least _____ hours to stimulate and maintain egg production; producers use artificial lighting to extend short natural days.

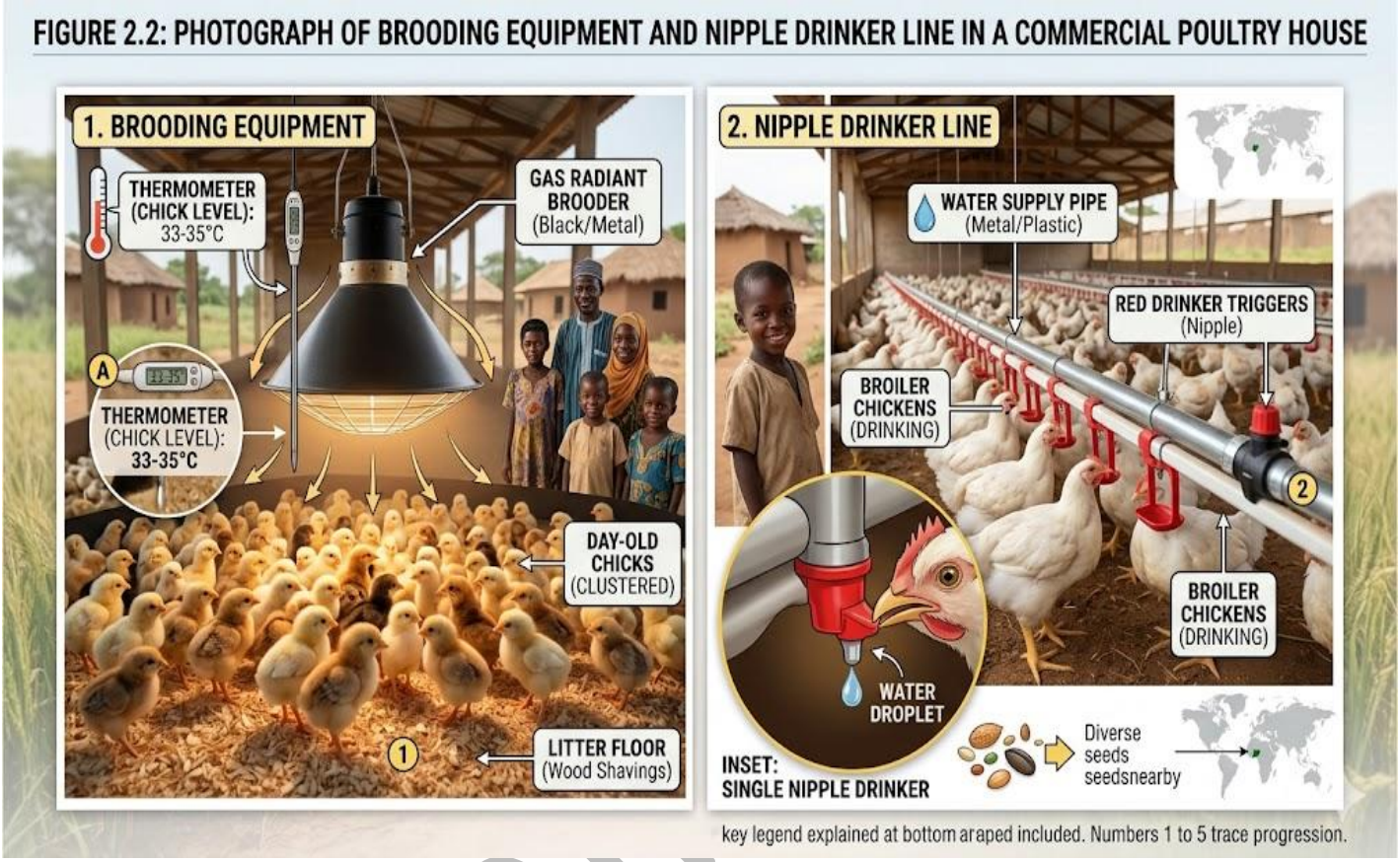

Figure 2.2: Photograph of brooding equipment and nipple drinker line in a commercial poultry house

2.2.3 Handling and sanitation equipment

Catching and handling equipment: catching nets for broilers; transport crates (hard plastic or wooden crates holding 8 to 12 broilers for transport to processing); leg bands and wing tags for identification. Weighing equipment: mechanical or digital hanging scale for weekly flock sample weighing; platform scale for feed bag weighing. Egg collection equipment: plastic or foam egg trays; egg washing machine for table egg operations; egg candling lamp for quality grading.

Sanitation equipment: high-pressure washer (removes organic matter from house surfaces, equipment, and vehicles); fogging machine (applies liquid disinfectant as a fine mist inside the house); sprayer (applies disinfectant to footbaths, vehicle entry points, and external surfaces); footbaths (trays of disinfectant solution placed at all house entrances). Litter management:

caking tools (fork and spade for removing wet, caked litter spots); litter turner for maintaining dry, friable litter throughout broiler grow-out.

Fill in the blank: A _____-pressure washer removes organic matter from house surfaces and equipment; disinfectant is ineffective if applied to surfaces still coated with organic material.

Pilot questions 2.2

1. Describe tubular feeders and pan feeders and state when each is used.
2. Distinguish between bell drinkers and nipple drinkers and state one advantage of nipple drinkers.
3. Describe gas brooders and state the correct brooding temperature for day-old chicks.
4. Explain the lighting programme for commercial layers and state why it is important.
5. State the correct sequence for cleaning and disinfecting a poultry house between batches.

2.3 The Hatching Egg and Incubation

2.3.1 Selection and handling of hatching eggs

Only eggs that meet strict quality criteria should be set for incubation. Selection criteria: weight 52 to 68 g (breed-specific; too small or too large reduces hatchability); shape (normal oval; abnormally long, round, or misshapen eggs are rejected); shell quality (clean, smooth, uncracked, free from shell defects; hairline cracks must be rejected as they allow bacterial entry); age (freshly laid eggs within 7 days are preferred; eggs older than 14 days have significantly reduced hatchability).

Storage conditions for hatching eggs: temperature 15 to 18 degrees Celsius (refrigeration at below 12 degrees Celsius damages the germinal disc); relative humidity 75 to 80 per cent; store with blunt end up to maintain air cell position; turn eggs daily if stored for more than 5 days to prevent the yolk from adhering to the shell membrane. For every day an egg is stored beyond 7 days, hatchability decreases by approximately 0.5 to 1 per cent per day.

Fill in the blank: Hatching eggs should be stored at _____ to 18 degrees Celsius with the blunt end up; hatchability declines by approximately 0.5 to 1 per cent for every day stored beyond 7 days.

2.3.2 Principles and requirements of incubation

Artificial incubation replicates the conditions a hen provides during natural brooding. Four critical physical requirements: temperature (37.5 to 37.8 degrees Celsius, measured at egg level in the setter; slightly cooler at 36.9 to 37.2 degrees in the hatcher during pipping and hatching); humidity (setter relative humidity 55 to 60%; hatcher relative humidity increased to 65 to 70% during the hatch period to prevent chicks from drying to the shell membrane).

Turning: eggs must be turned at least 6 to 8 times per day during days 1 to 18 of incubation to prevent the embryo from adhering to the shell membrane; turning is stopped on day 18 when eggs are transferred from the setter to the hatcher. Ventilation: CO2 must be kept below 0.5% in the setter; fresh air is critical for embryonic respiration. All four requirements must be simultaneously maintained; failure of any one significantly reduces hatchability.

Fill in the blank: Turning of eggs must be stopped on day _____ when eggs are transferred from the setter to the hatcher; turning after this point disturbs the chick as it positions itself for pipping.

Requirement	Details
Incubation Period	21 days total (18 days in setter + 3 days in hatcher)
Setter Temperature	37.5–37.8 °C
Hatcher Temperature	36.9–37.2 °C
Setter Humidity	55–60% RH
Hatcher Humidity	65–70% RH
Turning	6–8 times per day, days 1–18; stop turning on day 18
Ventilation	CO_2 below 0.5%; fresh air essential
Transfer to Hatcher	Day 18 (after candling to remove infertile/dead embryo eggs)
Hatch Window	Most chicks hatch days 20–21

Box 2.1: Summary of incubation requirements for chicken eggs

2.3.3 Types of incubators

Forced-air incubators use an electric fan to circulate warm air evenly throughout the incubator; temperature and humidity are uniform throughout the cabinet; standard for all commercial operations. Still-air incubators rely on natural convection; temperature is less uniform (the bottom of the incubator is cooler than the top); suitable only for very small operations or educational use. Modern commercial incubators are fully automated: electronic controllers manage temperature, humidity, turning, and alarms.

Setter-hatcher system: in large commercial hatcheries, a setter holds eggs for days 1 to 18 (one setter can hold 18 daily batches simultaneously); on day 18 eggs are candled, infertile and dead-embryo eggs removed, and fertile eggs transferred to a separate hatcher for the final 3 days. Single-stage incubation runs only one cohort of eggs per machine; multi-stage incubation runs multiple age cohorts simultaneously (more energy-efficient but increases cross-contamination risk between cohorts).

Fill in the blank: In the setter-hatcher system, eggs are transferred to the hatcher on day _____ after candling; the hatcher maintains higher humidity (65-70%) than the setter to prevent chicks drying to the shell.

Pilot questions 2.3

1. State four criteria for selecting a hatching egg.
2. Describe the correct storage conditions for hatching eggs.
3. State the four physical requirements of artificial incubation and give the correct value for each.
4. Explain why turning is necessary during incubation and when it should stop.
5. Distinguish between a setter and a hatcher and explain multi-stage versus single-stage incubation.

2.4 Hatchery Management

2.4.1 Hatchery layout and biosecurity

A commercial hatchery is designed on a strict clean-to-dirty flow principle: the movement of eggs, chicks, and personnel flows in one direction only (from clean areas toward dirty areas) to prevent pathogen transfer. Standard zones: egg receiving and fumigation room (dirty); egg storage room; setters room; transfer room (candling and transfer to hatcher); hatchery room (hatchers); chick processing room (vaccination, counting, boxing); dispatch area (clean). No backflow of personnel or materials from dirty to clean zones is permitted.

Biosecurity in the hatchery: all personnel entering the hatchery must shower and change into clean hatchery clothes and boots; no personal items may enter production areas; all incoming hatching egg cases and trays are fumigated before entry; the hatchery is cleaned and disinfected daily; air filtration (HEPA filters on air inlets) prevents airborne pathogen entry; hatchery waste (eggshells, dead-in-shell, unhatched eggs) must be disposed of as biohazard waste, not left accessible to wild birds or rodents.

Fill in the blank: The hatchery operates on a clean-to-_____ flow principle; personnel and materials move in one direction only to prevent pathogen transfer from dirty to clean zones.

2.4.2 Incubation management and candling

Daily incubation management tasks: check and record setter and hatcher temperature and humidity every 2 to 4 hours; verify that turning mechanism is functioning; monitor CO2 and adjust ventilation as needed; check water level in humidity reservoir; and record any alarms or deviations. Temperature deviations of more than 0.5 degrees Celsius for more than 2 hours significantly reduce hatchability; an experienced hatchery manager responds to any alarm within 30 minutes.

Candling is the examination of eggs using a bright light source (candling lamp) to assess embryo development. First candling at day 7 or 10: identifies infertile eggs (clear, no blood vessels visible) and early dead embryos (blood ring visible). Second candling (transfer candling) at day

18: removes any remaining infertile or dead eggs before transfer to the hatcher; this prevents exploding addled eggs contaminating the hatcher with bacteria. Hatchability of fertile eggs set (HFS) and hatchability of all eggs set (HES) are the key performance metrics.

Fill in the blank: Candling at day 7 or 10 identifies _____ eggs (no blood vessels visible) and early dead embryos (blood ring); these are removed to improve hatchery hygiene and hatchability data accuracy.

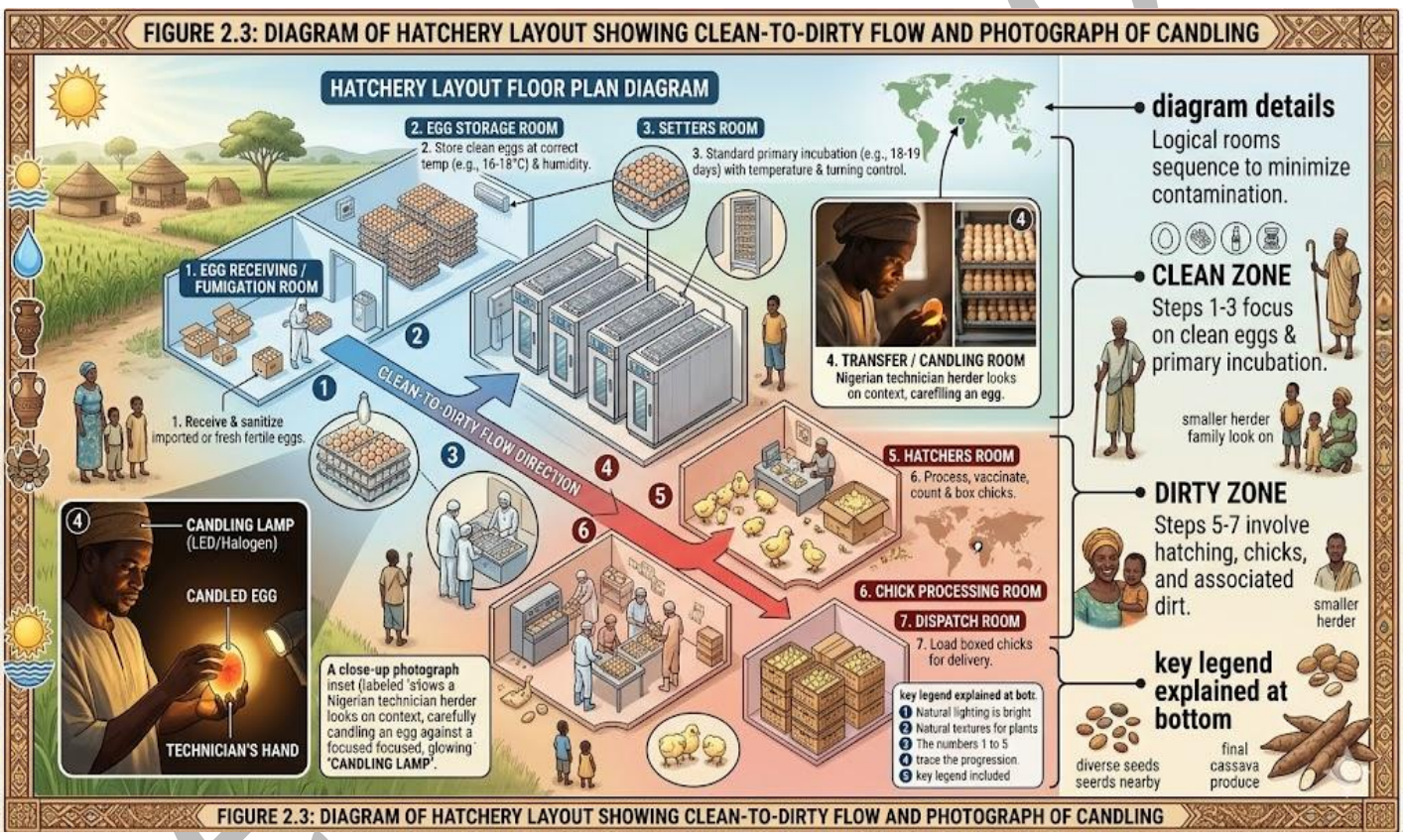

Figure 2.3: Diagram of hatchery layout showing clean-to-dirty flow and photograph of candling

2.4.3 Hatching, chick processing, and hatchery records

Most chicks hatch on days 20 to 21 of incubation. The hatch window (the time from first to last chick emerging) should be 24 to 36 hours for a quality flock of eggs; a prolonged hatch window (>48 hours) indicates poor egg storage, temperature variation, or weak parent stock. Chicks should be removed from the hatcher as soon as the flock is 95% hatched to prevent early-hatched chicks from desiccating; they can survive on absorbed yolk sac for up to 72 hours.

Chick processing: in the chick processing room, day-old chicks undergo vaccination (Marek's disease vaccine in ovo at day 18 or subcutaneously at hatch; Newcastle disease vaccine spray or eye-drop); sexing (for layer operations, males are removed; sexing is done by vent sexing or feather sexing for auto-sexing breeds); grading (removal of culls: wet chicks, deformed, small or unthrifty chicks); and counting and boxing (standard box holds 100 chicks with ventilation holes). Chicks should be dispatched within 6 hours of boxing.

Fill in the blank: Day-old chicks can survive on absorbed _____ sac nutrients for up to 72 hours after hatching; however, they should be dispatched to the farm within 6 hours of boxing to minimise stress.

Performance Record	Formula	Target Value
Fertility Rate	Fertile eggs ÷ Total eggs set × 100	>92% for parent stock flocks
Hatchability of Fertile Eggs Set (HFS)	Chicks hatched ÷ Fertile eggs set × 100	>88%
Hatchability of All Eggs Set (HES)	Chicks hatched ÷ Total eggs set × 100	>82%
First-Week Mortality (FWM)	Chicks dead in first 7 days ÷ Chicks placed × 100	<1%; high FWM indicates hatchery or transport problem
Cull Rate	Culled day-old chicks ÷ Total DOC hatched × 100	<2%
Hatch Window	Time from first to last chick hatched	24–36 hours

Box 2.2: Key hatchery performance records and target values

Pilot questions 2.4

1. Describe the clean-to-dirty flow principle in hatchery design and explain why it matters.
2. State five daily hatchery management tasks during incubation.
3. Explain what candling is and state what is identified at first and second candling.
4. Describe the chick processing steps after hatching.

5. Define HFS and HES and state the target value for each.

Series Summary

This Series covered housing, equipment, and hatchery management. Poultry house design principles (ventilation, shade, east-west orientation, 3 m eave height, 0.6-1 m overhang) and house types (open-sided, closed, curtain-sided, brooder, grow-out, layer, breeder) were described. Site selection requires elevated land, prevailing breeze access, 500 m biosecurity buffer, and 20-25 m inter-house spacing. Equipment: tubular and pan feeders (35-50 birds/pan), bell and nipple drinkers, gas brooders (33-35 degrees Celsius day 1), lighting programmes (16 hours for layers, 23 hours for broilers), natural and tunnel ventilation.

Hatching egg selection (52-68 g; clean, uncracked; under 7 days old), storage (15-18 degrees Celsius; 75-80% RH; blunt end up), and incubation requirements (setter 37.5-37.8 degrees Celsius, 55-60% RH; hatcher 36.9-37.2 degrees Celsius, 65-70% RH; turn days 1-18; stop day 18) were covered. Setter-hatcher systems with multi-stage and single-stage options were described. Hatchery management covered the clean-to-dirty flow layout, daily monitoring, candling (day 7/10 and day 18 transfer), chick processing (vaccination, sexing, grading, boxing), and performance records (HFS >88%, HES >82%, FWM <1%). By completing this Series, you should achieve all seven SLOs (2.1 to 2.7).

Glossary of Terms

- **Battery cage:** a wire housing system for laying hens; also described in Series 1.
- **Bell drinker:** a hanging bell-shaped open drinker filled by a float valve; inexpensive; common for chicks and small flocks.

- **Brooder:** a device providing supplementary heat for young chicks; gas radiant brooders are most common in Nigerian commercial production.
- **Candling:** examination of an egg against a bright light source to assess embryo development; used at day 7-10 and day 18.
- **Chick processing:** post-hatch handling of day-old chicks including vaccination, sexing, grading, counting, and boxing before dispatch.
- **Clean-to-dirty flow:** the unidirectional movement of eggs, chicks, and personnel through a hatchery from clean receiving areas to dirty dispatch areas.
- **Controlled environment house:** a fully enclosed poultry house with mechanical ventilation and evaporative cooling; allows precise environmental management.
- **Cull rate:** percentage of day-old chicks removed as unacceptable (wet, deformed, small, unthrifty) at the hatchery; target <2%.
- **First-week mortality (FWM):** percentage of placed chicks dying in the first 7 days; target <1%; elevated FWM indicates a hatchery or transport problem.
- **Forced-air incubator:** an incubator using a fan to circulate warm air evenly throughout the cabinet; standard for all commercial incubation.
- **Hatchability of all eggs set (HES):** chicks hatched / total eggs set x 100; target >82%.
- **Hatchability of fertile eggs set (HFS):** chicks hatched / fertile eggs set x 100; target >88%.
- **Hatch window:** the time from first to last chick emerging in a batch; target 24-36 hours; prolonged window indicates quality problems.
- **Hatcher:** the incubator section used for the final 3 days of incubation (days 18-21) at higher humidity to facilitate hatching.
- **Multi-stage incubation:** running multiple cohorts of eggs of different ages simultaneously in one setter; more energy-efficient but increases cross-contamination risk.

- **Nipple drinker:** a water delivery device from which birds drink by pecking a metal nipple; reduces wastage and contamination; standard in commercial houses.
- **Open-sided house:** a poultry house with wire mesh or curtain sidewalls to maximise natural ventilation; most common type in Nigeria.
- **Pan feeder:** a circular feed pan on an automated feed line; standard in modern commercial broiler houses.
- **Setter:** the incubator section used for days 1-18 of incubation; holds eggs in turning trays.
- **Single-stage incubation:** running only one cohort of eggs per machine; reduces cross-contamination risk but is less energy-efficient.
- **Still-air incubator:** an incubator relying on natural convection; temperature less uniform; suitable only for small or educational operations.
- **Tunnel ventilation:** a ventilation system in which all fans are at one end of the house and air inlets at the other; creates a high-speed air stream; standard in closed houses.

Concept Check Questions [Series 2]

Objective Questions

1. The long axis of a poultry house should be oriented _____-west to minimise direct solar radiation on sidewalls. (Linked to SLO 2.2)
2. Nipple drinkers require a water pressure of _____ to 25 psi; they reduce water wastage compared with open bell drinkers. (Linked to SLO 2.3)
3. Laying hens require at least _____ hours of light per day to maintain egg production. (Linked to SLO 2.3)
4. Hatching eggs should be stored at 15 to _____ degrees Celsius with the blunt end upward. (Linked to SLO 2.4)

5. Egg turning is stopped on day _____ when eggs are transferred from the setter to the hatcher. (Linked to SLO 2.5)

Short-Answer Questions

6. State five principles of poultry house design. (Linked to SLO 2.1)
7. Distinguish between bell drinkers and nipple drinkers. (Linked to SLO 2.3)
8. State the four physical requirements of incubation and the correct value for each in the setter. (Linked to SLO 2.5)
9. Explain what candling is and state what is identified at first candling and at transfer candling. (Linked to SLO 2.7)
10. Define HFS and HES and state the target value for each. (Linked to SLO 2.7)

Long-Answer Questions

11. Describe the principles of poultry house design, the types of poultry houses, and the criteria for site selection and house orientation. (Linked to SLOs 2.1, 2.2)
12. Describe the major feeding, watering, heating, lighting, and ventilation equipment used in commercial poultry production. (Linked to SLO 2.3)
13. Describe the selection and storage of hatching eggs, the principles of incubation, the types of incubators, and the management of a commercial hatchery from setting through chick processing. (Linked to SLOs 2.4, 2.5, 2.6, 2.7)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. East.

2. 15.
3. 16.
4. 18.
5. 18.

Short-Answer Questions

6. Protection from predators, rain, and sun; maintain optimal temperature; adequate ventilation (remove heat, moisture, ammonia, CO2); easy to clean and disinfect; economical to build and maintain.
7. Bell drinkers are open hanging vessels filled by float valve; inexpensive; water exposed to contamination and evaporation. Nipple drinkers deliver water drop-by-drop when pecked; reduce wastage and contamination; require 15-25 psi water pressure; standard in commercial houses.
8. Temperature: 37.5-37.8 degrees Celsius at egg level; humidity: 55-60% RH; turning: 6-8 times per day; ventilation: CO2 below 0.5%.
9. Candling examines eggs against a bright light to assess embryo development. First candling (day 7-10): identifies infertile eggs (clear) and early dead embryos (blood ring); both are removed. Transfer candling (day 18): removes remaining infertile or dead-embryo eggs before transfer to hatcher to prevent bacterial explosion.
10. HFS = chicks hatched / fertile eggs set x 100; target >88%. HES = chicks hatched / total eggs set x 100; target >82%.

Long-Answer Questions

11. Design principles: protection from predators/rain/sun; optimal temperature (18-24 degrees Celsius adults; 33-35 chicks); adequate ventilation (ammonia, moisture, CO2 removal); easy clean and disinfect; economical construction. Types: open-sided tropical (wire mesh/curtain walls; natural ventilation; most common in Nigeria); closed

controlled-environment (mechanical fans, evaporative cooling; expensive; precise control); curtain-sided (adjustable); brooder house (heavily insulated; 33-35 degrees Celsius); grow-out house (standard broiler floor system); layer house with cages; breeder house with nest boxes. Site selection: elevated well-drained land (prevents flooding and dampness); prevailing breeze for cross-ventilation; 500 m biosecurity buffer from other farms; reliable water supply; road access for feed delivery and product transport. Orientation: long axis east-west to minimise sidewall solar radiation; roof overhang 0.6-1 m; roof height minimum 3 m at eave; house spacing 20-25 m apart; staggered alignment to prevent exhaust air entering adjacent house inlet.

12. Feeding: tubular feeders (hanging, self-filling; standard floor system; 35-50 birds per feeder); pan feeders (automated feed lines; standard modern commercial broiler house); trough feeders (battery cages, chicks). Watering: bell drinkers (float-valve open vessel; inexpensive; for chicks and small flocks); nipple drinkers (metal nipple; one drop per peck; 15-25 psi pressure; reduces wastage and contamination; commercial standard). Water consumption = 1.5-2x feed consumption; drinker height adjusted as birds grow. Heating: gas radiant brooder (propane/butane; 2,500 kcal/hour; 500 chicks per unit; most common); electric infrared brooder; hover brooder; temperature 33-35 degrees Celsius day 1, reduced 2-3 degrees per week. Lighting: 23L:1D for broilers (maximise growth); 8 hours increasing to 16 hours for layers (stimulate and maintain production); LED preferred over incandescent. Ventilation: natural cross-ventilation in open-sided houses; tunnel ventilation (fans at one end, inlets at other) in closed houses; removes heat, moisture, ammonia, CO2; minimum ventilation prevents ammonia accumulation even in cold periods.
13. Hatching egg selection: weight 52-68 g; normal oval shape; clean uncracked shell; under 7 days old (preferred) or maximum 14 days. Storage: 15-18 degrees Celsius; 75-80% RH; blunt end up; turn daily if stored >5 days; hatchability declines 0.5-1%/day beyond 7 days. Incubation requirements: setter temperature 37.5-37.8 degrees Celsius; hatcher 36.9-37.2 degrees Celsius; setter humidity 55-60% RH; hatcher 65-70% RH; turning 6-8 times/day days 1-18; stop day 18; CO2 <0.5%; total incubation 21 days (18 in setter + 3 in hatcher). Incubator types: forced-air (fan circulates air evenly; commercial standard); still-air (natural convection; uneven temperature; educational use only); automated

(electronic controller manages all parameters). Setter-hatcher system: setter holds up to 18 daily batches simultaneously; transfer day 18 after candling. Multi-stage (multiple cohorts in one machine; efficient but cross-contamination risk) vs single-stage (one cohort; cleaner but less efficient). Hatchery management: clean-to-dirty flow (egg receiving → storage → setters → transfer/candling → hatchers → chick processing → dispatch; no backflow); biosecurity (shower and change clothes; fumigate incoming eggs; HEPA air filtration; biohazard waste disposal); daily monitoring (temperature and humidity every 2-4 hours; verify turning; CO2; water level); candling (day 7-10: remove clear and blood ring; day 18: final removal before transfer). Chick processing: vaccination (Marek's disease in ovo or subcutaneous; Newcastle disease spray/eye-drop); sexing; grading (remove culls); counting and boxing (100 per box); dispatch within 6 hours. Performance records: HFS >88%; HES >82%; FWM <1%; cull rate <2%; hatch window 24-36 hours.

Answers to Pilot Questions [Series 2]

Part 2.1

1. Five principles: (1) protect from predators, rain, and direct sun; (2) maintain optimal temperature (18-24 degrees Celsius for adults, 33-35 for chicks); (3) ensure adequate ventilation to remove heat, moisture, ammonia, and CO2; (4) easy to clean and disinfect between batches; (5) economical to construct and maintain using locally available materials.
2. Open-sided house: wire mesh or curtain sidewalls; relies entirely on natural cross-ventilation; low capital cost; suitable for Nigeria's tropical climate; standard for most Nigerian broiler and layer farms. Closed controlled-environment house: fully enclosed; mechanical ventilation fans and evaporative cooling pads; precise temperature and air quality control; high capital and energy cost; used for high-density commercial broilers or where climate is extreme.

3. When the long axis is oriented east-west, the long sidewalls face north and south; the sun rises and sets along the short axis ends of the house, not directly into the sidewalls. This minimises the duration and intensity of direct solar radiation striking the broad sidewall surfaces, which would heat the interior significantly. In Nigeria's tropical climate, solar heat load is the dominant thermal challenge; an east-west orientation combined with wide roof overhangs can reduce internal temperature by 2 to 5 degrees Celsius compared with a north-south oriented house.
4. Five site selection criteria: (1) elevated, well-drained land (prevents flooding and ground moisture that predisposes to respiratory disease and dirty litter); (2) alignment with prevailing breeze direction (maximises natural ventilation through open-sided houses); (3) minimum 500 m biosecurity buffer from other poultry farms or live bird markets (reduces airborne disease risk); (4) reliable, clean water supply (poultry water needs 1.5-2x feed consumption; water quality directly affects health and production); (5) accessible road for feed delivery, chick delivery, and product collection.
5. Correct inter-house spacing (20-25 m, equal to one house width) ensures: (1) adequate airflow between houses to prevent the exhaust air from one house (laden with ammonia, dust, and pathogens) from entering the inlets of the adjacent house; (2) sufficient light and air movement to keep the inter-house ground dry (wet ground between houses is a reservoir for Eimeria, Salmonella, and Histomonas pathogens); (3) independent biosecurity management — a disease event in one house does not automatically compromise adjacent houses if spacing and staggered layout are maintained.

Part 2.2

1. Tubular feeders: hanging cylindrical tube feeders suspended from the roof structure on a cable or chain; feed fills from a central hopper above the tube by gravity or auger; birds eat from the circular tray at the bottom; used for broilers and pullets on floor systems; each tube accommodates 35-50 birds. Pan feeders: circular feed pans on automated conveyor or auger feed lines that extend the length of the house; feed is delivered to each

pan automatically from a central bulk bin; standard in modern commercial broiler houses; allow very precise feed delivery and reduced labour.

2. Bell drinkers: hanging bell-shaped open water vessels connected to a float valve; water fills automatically to a fixed level; birds drink from the rim of the open trough; inexpensive; widely used for day-old chick placement and small flocks; disadvantage: open water surface allows contamination by litter, feed, and faeces, and water spills wet the litter. Nipple drinkers: birds peck a spring-loaded metal nipple at the bottom of a water delivery tube; each peck releases one drop of water; water stays enclosed until released; advantage over bell drinkers: eliminates open water surface; dramatically reduces spillage, litter wetting, and bacterial contamination; reduces water consumption waste; requires 15-25 psi water pressure; standard in all commercial Nigerian broiler and layer houses.
3. Gas radiant brooder: a disc-shaped propane or butane gas-fuelled radiant heating element suspended from the roof or ceiling above the chicks; fuel combustion heats the ceramic disc which radiates infrared heat downward to the chick zone; typical capacity 2,500 kcal/hour, covering approximately 500 day-old chicks per brooder unit; each brooder is connected to a gas supply by flexible hose with a regulator. Correct brooding temperature: 33 to 35 degrees Celsius measured at chick level (not at brooder level) on day 1 of placement; temperature is reduced by 2 to 3 degrees Celsius per week as chicks develop thermoregulatory capacity; by week 3, supplementary heat is usually no longer required in Nigerian conditions.
4. Lighting programme for commercial layers: week 1 to week 14 (pullet growing phase) the daylength is kept at 8 to 10 hours (short day) to prevent premature sexual maturity; from week 15 to 17 (pre-lay stimulation) the daylength is increased by 1 hour per week from 10 to 14 hours; at point of lay (18 to 19 weeks) daylength is stepped up to 16 hours (or the natural day length if longer) and maintained at 16 to 17 hours throughout the laying cycle. Importance: daylength controls the release of gonadotropin-releasing hormone (GnRH) from the hypothalamus which triggers the pituitary to release LH and FSH, stimulating ovarian follicle development and ovulation; inadequate daylength delays or suppresses production; decreasing daylength causes a production drop and may trigger a moult.

5. Correct sequence for cleaning and disinfecting a poultry house: (1) depopulate (remove all birds); (2) remove all feed from feeders and bins; (3) remove all equipment (feeders, drinkers, brooders) from the house; (4) remove all litter and organic material by scraping and shovelling; (5) dry sweep walls, ceilings, and ledges; (6) high-pressure wash all surfaces (floor, walls, ceiling, roof beams, equipment) with plain water to remove all organic material; (7) allow to dry; (8) apply disinfectant (spray or fogging) at the correct dilution rate; (9) allow minimum 48-hour contact time; (10) optionally fumigate with formaldehyde gas for 24 hours; (11) rest house empty for minimum 2 weeks before next placement.

Part 2.3

1. Four selection criteria for hatching eggs: (1) correct weight (52-68 g for chicken; too light or too heavy reduces hatchability and chick quality); (2) normal oval shape (abnormally elongated, round, or double-yolk eggs are rejected; shape affects air cell position and chick orientation at hatch); (3) shell quality (smooth, clean, uncracked; hairline cracks allow bacterial contamination of the albumen; dirty or faecally-contaminated shells are rejected or fumigated); (4) age (freshly laid within 7 days preferred; maximum 14 days; hatchability declines approximately 0.5-1% per day beyond 7 days of storage).
2. Correct storage conditions: temperature 15-18 degrees Celsius (too cold, below 12 degrees Celsius, damages the germinal disc; too warm, above 22 degrees Celsius, allows early embryonic development before setting); relative humidity 75-80% (lower humidity desiccates the egg; higher humidity promotes mould growth); position blunt end uppermost (maintains air cell in correct position and prevents yolk from settling against the shell membrane at the equator, which causes embryo adhesion); turn eggs through 45 degrees once daily if stored for more than 5 days (prevents yolk from adhering to the shell membrane during extended storage).
3. Four physical requirements and correct setter values: (1) temperature 37.5-37.8 degrees Celsius measured at egg level in the setter; (2) relative humidity 55-60% in the setter (65-70% in the hatcher during hatching); (3) turning 6-8 times per day from day 1 to day 18

of incubation (stop turning on day 18 when transferred to hatcher); (4) ventilation CO2 below 0.5% (fresh air needed for embryonic respiration; CO2 accumulation is toxic to the developing embryo).

4. Turning is necessary because: the developing embryo is lighter than the surrounding albumen and floats upward; without turning, the embryo settles against the shell membrane and adheres to it, preventing normal development of the allantois and causing embryonic death. Turning must occur at least 6-8 times per day to maintain appropriate yolk-albumen mixing and embryo position. Turning must stop on day 18 of incubation (transfer day) because at this point the embryo begins positioning itself for pipping (breaking through the inner shell membrane and air cell and then through the shell); turning after day 18 disrupts this positioning process and increases late-embryo mortality and malposition at hatch.
5. Setter: the incubator section used for days 1 to 18 of the 21-day incubation period; maintains 37.5-37.8 degrees Celsius and 55-60% RH; eggs are placed in turning trays that rotate automatically 6-8 times per day; one commercial setter can hold 18 daily batches simultaneously (multi-stage) or a single cohort (single-stage). Hatcher: a separate incubator cabinet used for days 18-21; maintains slightly lower temperature (36.9-37.2 degrees Celsius) and higher humidity (65-70% RH) to facilitate hatching; no turning mechanism; eggs transferred from setter to hatcher in hatching baskets after transfer candling on day 18. Single-stage: one cohort of eggs per machine; lower cross-contamination between cohorts; stricter hygiene; higher energy cost. Multi-stage: 18 cohorts of different ages simultaneously in one setter; more energy-efficient; risk of older contaminated chicks/eggs affecting younger cohorts.

Part 2.4

1. The clean-to-dirty flow principle organises the hatchery so that eggs, chicks, personnel, and materials move continuously in one direction, from the cleanest areas (incoming hatching eggs) to progressively less clean areas (hatch debris and outgoing waste), with no backflow. Zones in order of cleanliness: egg receiving/fumigation → egg storage →

setters room → transfer/candling room → hatchers room → chick processing room → dispatch. It matters because: hatcheries handle millions of embryos and day-old chicks with no immune system; a single Salmonella, E. coli, or Mycoplasma contamination event can spread to thousands of chicks simultaneously; the clean-to-dirty flow, combined with footbaths, showers, and zonal biosecurity, prevents pathogens entering the clean zones.

2. Five daily tasks: (1) check and record setter and hatcher temperature every 2-4 hours and verify readings against calibrated reference thermometers; (2) check and record relative humidity in setters and hatchers; (3) visually verify that egg-turning mechanisms are operating in all setters (a turning failure over 8 hours significantly increases late embryonic mortality); (4) check CO2 levels and adjust ventilation settings as needed to maintain CO2 below 0.5%; (5) check water level in humidity reservoir tanks and refill if needed to maintain target humidity.
3. Candling is the inspection of eggs against a powerful focussed light source (candling lamp) to observe the internal contents through the shell. First candling at day 7 or 10: (1) infertile eggs appear clear (transparent) with no visible blood vessel network; (2) early dead embryos show a blood ring (a ring of blood where the embryo died and the blood vessels ruptured and spread); both are removed from the setter, reducing contamination risk and improving accuracy of hatchability calculations. Transfer candling at day 18: any remaining infertile or dead eggs are removed; exploding addled eggs in the hatcher can shower thousands of chicks and hatcher surfaces with bacteria, causing hatch contamination.
4. Chick processing steps after hatching: (1) remove chicks from hatchers when 95% of the flock has hatched (typically 20-21 hours after the hatch window opens); (2) vaccination — Marek's disease vaccine administered in ovo on day 18 (most common in large hatcheries) or subcutaneously at the back of the neck at hatch; Newcastle disease (ND) vaccine spray or eye-drop in ovo or at hatch; (3) sexing — vent sexing by trained technician or feather sexing for auto-sexing breeds (layer operations remove males at this stage); (4) grading — remove culls (wet, deformed, navel-unhealed, lethargic, or severely undersized chicks); (5) counting and boxing — 100 chicks per standard ventilated

cardboard chick box; (6) dispatch — boxes loaded into temperature-controlled vehicle and delivered to farms within 6 hours of boxing.

5. HFS (Hatchability of Fertile Eggs Set) = (number of chicks hatched / number of fertile eggs set) x 100; target >88%; it measures the efficiency of the incubation process itself, excluding the influence of infertility. HES (Hatchability of All Eggs Set) = (number of chicks hatched / total number of eggs set) x 100; target >82%; it measures the overall hatchery output efficiency including the effect of infertility; HES is the more comprehensive commercial performance metric because it includes the cost of all eggs set.

References and Attributions [Series 2]

Textual References (Books and External Sources)

- North, M. O., & Bell, D. D. (1990). Commercial chicken production manual (4th ed.). Van Nostrand Reinhold.
- Tullett, S. G. (Ed.). (1991). Avian incubation. Butterworth-Heinemann.
- Cobb-Vantress. (2022). Cobb broiler management guide. Cobb-Vantress.
- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.

Figures, Plates, Tables, and Boxes

- Figure 2.1: Open-sided tropical poultry house diagram and photograph Attribution: AI generated. Suggested OER search string: "open-sided tropical poultry house Nigeria design diagram photograph OER".
- Figure 2.2: Brooding equipment and nipple drinker line photograph Attribution: AI generated. Suggested OER search string: "gas brooder day-old chicks nipple drinker poultry house photograph OER".

- Box 2.1: Incubation requirements for chicken eggs summary Attribution: AI generated. Suggested OER search string: "chicken egg incubation requirements summary temperature humidity turning OER box".
- Figure 2.3: Hatchery layout diagram and candling photograph Attribution: AI generated. Suggested OER search string: "hatchery layout clean dirty flow diagram candling photograph OER".
- Box 2.2: Hatchery performance records and targets Attribution: AI generated. Suggested OER search string: "hatchery performance records fertility hatchability first week mortality target OER box".

Course code: AGE 406

Course title: Poultry Production Education

Course credit load: 2 Units

Series 3: Breeding, Feeding, and Rearing Practices

- **Part 3.1: Poultry Breeding and Breeder Management**
  - Sub Part 3.1.1: Breeder flock management
  - Sub Part 3.1.2: Natural mating and artificial insemination
  - Sub Part 3.1.3: Breeder nutrition and fertility
- **Part 3.2: Poultry Nutrition and Feeding**
  - Sub Part 3.2.1: Nutrient requirements of poultry
  - Sub Part 3.2.2: Feed ingredients and formulation
  - Sub Part 3.2.3: Feeding phases and programmes
- **Part 3.3: Broiler Rearing Practices**
  - Sub Part 3.3.1: Broiler placement and brooding management
  - Sub Part 3.3.2: Broiler grow-out management
  - Sub Part 3.3.3: Broiler health and pre-slaughter management
- **Part 3.4: Layer and Pullet Rearing Practices**
  - Sub Part 3.4.1: Pullet rearing from day old to point of lay
  - Sub Part 3.4.2: Layer management during the production period

- Sub Part 3.4.3: Turkey, duck, and guinea fowl rearing

Introduction

The productivity of any poultry flock is determined by three interlocking pillars: genetics (the breed or hybrid), nutrition (what the bird eats), and management (how it is reared). A genetically superior bird on a poor diet in a poorly managed house will underperform; an ordinary bird on a well-balanced diet under careful management will often exceed expectations.

This Series covers breeder flock management, natural and artificial insemination, poultry nutrition and feed formulation, the feeding phases for broilers and layers, broiler placement through pre-slaughter management, and pullet and layer management. Turkey, duck, and guinea fowl rearing are also introduced.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** describe breeder flock management, natural mating, and artificial insemination in poultry (Linked to Part 3.1),
- **SLO 3.2** describe the nutrient requirements of poultry and explain the role of each nutrient class (Linked to Part 3.2),
- **SLO 3.3** describe poultry feed ingredients, feed formulation principles, and feeding programmes for broilers and layers (Linked to Part 3.2),
- **SLO 3.4** describe the management of broiler flocks from placement through pre-slaughter (Linked to Part 3.3),
- **SLO 3.5** describe pullet rearing from day old to point of lay (Linked to Part 3.4),
- **SLO 3.6** describe layer management during the production period (Linked to Part 3.4), and

- **SLO 3.7** describe the rearing practices for turkeys, ducks, and guinea fowl (Linked to Part 3.4).

3.1 Poultry Breeding and Breeder Management

3.1.1 Breeder flock management

A breeder flock is a flock of sexually mature male and female birds maintained to produce fertile hatching eggs. Commercial broiler breeders are managed as floor flocks with males and females housed together at a ratio of 1 male per 8 to 10 females. Breeder houses are equipped with nest boxes (one nest per 5 to 6 females) to collect clean, undamaged hatching eggs. Nest box design, placement, and training of hens to use them are critical to hatching egg quality.

Breeder body weight control is the most critical management challenge. Broiler breeders (especially females) have a genetic tendency to overeat; overweight breeders have poor fertility, reduced egg production, and leg problems. Feed restriction (providing only 60 to 80 per cent of ad libitum intake) from day old through the production period is standard practice. Skip-a-day feeding (feeding every other day) is also used to achieve weight targets while maintaining bird satisfaction.

Fill in the blank: Broiler breeders are fed on a restricted programme providing _____ to 80 per cent of ad libitum intake to prevent overweight, which impairs fertility, egg production, and leg soundness.

3.1.2 Natural mating and artificial insemination

In natural mating, males and females are housed together and mating occurs freely. Male-to-female ratio is critical: too few males results in infertile eggs; too many causes over-mating, stressing and injuring hens. For broiler breeders: 1 male per 8 to 10 females; for turkey: 1 tom per 10 to 12 hens in natural mating; for layers: 1 male per 10 to 15 females. Males are selected for body weight, conformation, libido, and sperm quality.

Artificial insemination (AI) is standard in commercial turkey production because the broad-breasted turkey breeds are too heavy for efficient natural mating. AI involves collecting semen from males (by massage of the abdomen and milking the phallus), diluting with a saline extender, and inseminating hens by inserting a syringe or cannula into the oviduct. Turkeys are inseminated every 10 to 14 days. AI is also used in layer breeding programmes to control parentage precisely.

Fill in the blank: Artificial insemination (AI) is standard in commercial turkey production because broad-breasted toms are too heavy for _____ mating; hens are inseminated every 10 to 14 days.

3.1.3 Breeder nutrition and fertility

Breeder nutrition must support egg production, fertility, and the nutritional quality of the hatching egg (which provides the sole nutrition for the developing embryo). Key nutrients: protein and lysine for egg albumen synthesis; calcium and phosphorus for shell formation (breeder diets contain 3.0 to 3.5% calcium); vitamin A and E for fertility (vitamin E is critical for spermatogenesis and embryo development); vitamin D3 for calcium metabolism and shell quality.

Selenium and zinc deficiency reduce male fertility and sperm quality. Manganese deficiency causes perosis (slipped tendon) in chicks from deficient breeders. Biotin deficiency causes fatty liver and kidney syndrome. Breeder diets are carefully formulated to ensure that the hatching egg is well-supplied with all fat-soluble vitamins and trace minerals necessary for embryo development; this is why breeder diets differ significantly in composition from layer diets despite similar egg production targets.

Fill in the blank: Vitamin _____ is critical for spermatogenesis and embryo development in breeders; deficiency reduces fertility and increases early embryo mortality.

Pilot questions 3.1

1. Explain why body weight control is critical for broiler breeder females.

2. State the recommended male-to-female ratio for broiler breeders and for turkeys under natural mating.
3. Explain why AI is standard practice in commercial turkey production.
4. State three nutrients that are particularly important in breeder diets and explain the role of each.
5. Explain what perosis is and which nutrient deficiency causes it in chicks.

3.2 Poultry Nutrition and Feeding

3.2.1 Nutrient requirements of poultry

Poultry require six classes of nutrients. Energy (from carbohydrates and fats) is the primary driver of feed intake: birds eat to meet their energy needs first. Metabolisable energy (ME) is expressed in kcal/kg or MJ/kg and is the energy available to the bird after digestive losses. Protein provides amino acids; the essential amino acids most limiting in poultry diets are lysine, methionine, threonine, and tryptophan; methionine is the first-limiting amino acid in maize-soyabean diets.

Minerals: calcium (2.0-4.0% of diet depending on production phase) and phosphorus (0.35-0.45% available P) for bone and shell; sodium chloride (0.15-0.20%) for electrolyte balance; trace minerals (zinc, manganese, copper, selenium, iodine) for enzyme function and reproduction. Vitamins: fat-soluble (A, D3, E, K) and water-soluble (B-complex, C). Water is the most critical nutrient: a 10% reduction in water intake causes a 10% fall in egg production; complete deprivation for 24 hours can be fatal.

Fill in the blank: _____ is the first-limiting amino acid in maize-soyabean poultry diets; its deficiency reduces growth rate and egg production more than any other single amino acid.

3.2.2 Feed ingredients and formulation

Energy ingredients: maize (the primary energy source in Nigerian poultry diets; 8.5 to 9.0 MJ ME/kg; 8.5% crude protein); sorghum (similar energy value to maize; less common); wheat offals and rice bran (lower energy; used to reduce diet cost). Protein ingredients: soyabean meal (44 to 48% crude protein; the primary protein source; provides well-balanced amino acids); groundnut cake (45% CP; widely used in northern Nigeria; aflatoxin risk requires quality control); fish meal (65% CP; highly digestible; expensive; used at low levels).

Mineral and vitamin supplements: dicalcium phosphate or bone meal (calcium and phosphorus); limestone or oyster shell (calcium for layers); salt (sodium chloride); commercial vitamin-mineral premix (contains all required vitamins and trace minerals). Feed formulation uses least-cost methods (linear programming software) to combine ingredients to meet all nutrient specifications at minimum cost. The Pearson square can be used for simple two-ingredient protein balancing.

Fill in the blank: Soyabean meal contains _____ to 48 per cent crude protein and provides a well-balanced amino acid profile; it is the primary protein source in Nigerian commercial poultry diets.

Diet Phase	ME (kcal/kg)	Crude Protein (%)	Lysine (%)	Methionine (%)	Calcium (%)
Broiler Starter (0–10 days)	3,100	23	1.25	0.55	–
Broiler Grower (11–28 days)	3,100	21	1.10	0.48	–
Broiler Finisher (29+ days)	3,200	19	0.95	0.40	–
Layer (in production)	2,750	17	0.80	0.38	3.8

Box 3.1: Typical nutrient specifications for commercial Nigerian poultry diets by production phase

3.2.3 Feeding phases and programmes

Broilers are fed in three phases: starter (day 1 to 10; high protein 22 to 24%; crumble or small pellet form); grower (day 11 to 28; protein reduced to 20 to 22%; pellet); finisher (day 29 to slaughter; protein 18 to 20%; pellet; may be withdrawal diet free of certain additives for pre-slaughter period). Ad libitum feeding throughout maximises growth rate and FCR. Feed form (mash, crumble, or pellet) affects intake and FCR; pelleting improves FCR by 5 to 10%.

Layers are fed in four phases: chick starter (0 to 6 weeks); pullet grower (6 to 12 weeks); pullet developer (12 to 18 weeks; calcium deliberately kept low to prevent premature calcium deposition in bones); layer diet (18 weeks onwards; calcium increased to 3.5 to 4.0% as production begins). Layer feeding is controlled in amount but ad libitum in access; overfeeding layers causes excessive body fat, reduced egg production, and prolapse. Wet feed (mash mixed with water) increases palatability and intake in hot weather.

Fill in the blank: The pullet _____ diet (12 to 18 weeks) deliberately contains low calcium to prevent premature calcium deposition in bones before the reproductive tract is mature.

Pilot questions 3.2

1. State six nutrient classes required by poultry and give one function of each.
2. Explain why methionine is described as the first-limiting amino acid in Nigerian poultry diets.
3. Name three energy ingredients and three protein ingredients used in Nigerian poultry feeds.
4. Describe the three feeding phases for broilers and state the key difference between them.
5. Explain why pullet developer diet contains low calcium.

3.3 Broiler Rearing Practices

3.3.1 Broiler placement and brooding management

Before placement, the house must be thoroughly cleaned, disinfected, and rested (minimum 2 weeks after previous batch); litter (wood shavings, rice husks, or sawdust) is spread 5 to 8 cm deep; feeders and drinkers are placed and filled; and the brooder is lit 24 hours before chick arrival to pre-warm the house to 33 to 35 degrees Celsius at chick level. Day-old chicks are placed at a density of 10 to 15 birds per m2 depending on target slaughter weight and season.

During brooding (week 1 to 2), the key management task is monitoring chick behaviour as an indicator of thermal comfort: chicks huddled under the brooder indicate cold; chicks spread to the edges indicate heat; even distribution indicates correct temperature. Temperature is reduced 2 to 3 degrees Celsius per week. Water must be provided immediately on placement; drinker height is adjusted daily as chicks grow. Observe chick comfort, feed and water intake, and litter condition at least twice daily.

Fill in the blank: Chicks _____ under the brooder indicate that the temperature is too cold; chicks spread to the edges of the house indicate too much heat.

FIGURE 3.1: PHOTOGRAPH SHOWING BROILER CHICK DISTRIBUTION PATTERNS INDICATING THERMAL COMFORT AND DISCOMFORT

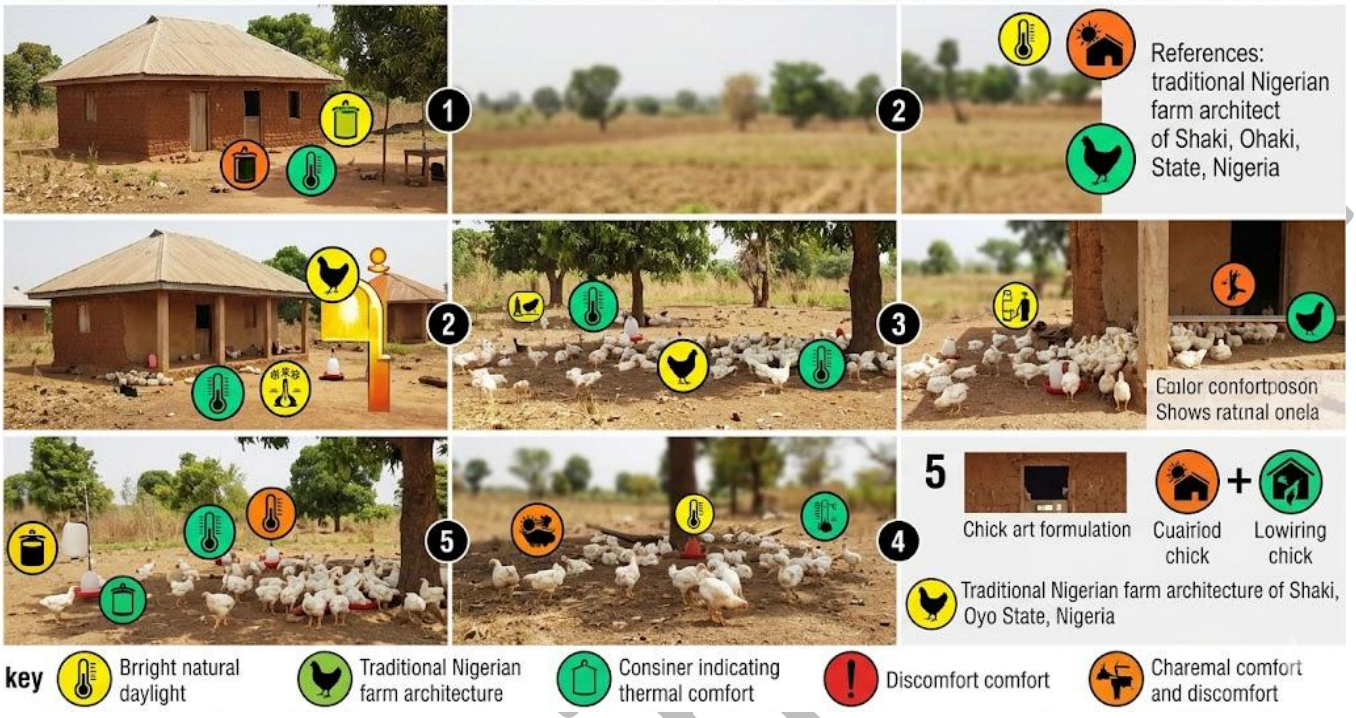

Figure 3.1: Photograph showing broiler chick distribution patterns indicating thermal comfort and discomfort

3.3.2 Broiler grow-out management

From week 2 to slaughter (usually 5 to 6 weeks), key grow-out management practices include: weekly body weight sampling (5% of flock) and comparison against breed performance standards; daily feed and water consumption recording; litter management (maintain dry, friable litter by increasing ventilation, removing wet patches, and avoiding drinker spillage); and daily mortality recording and removal. Flock uniformity target: coefficient of variation below 10%.

Stocking density management: reduce density (thin out) by removing a proportion of the flock to market or a secondary house at 28 to 35 days; this improves growth performance and welfare of the remaining birds. Ventilation management is critical in hot Nigerian conditions; high air speed (minimum 2 to 3 m/s in tunnel-ventilated houses) provides wind chill cooling. Temperature inside the house should not exceed 30 degrees Celsius at any time; above 35 degrees Celsius causes severe heat stress and elevated mortality.

Fill in the blank: Air speed in tunnel-ventilated broiler houses should be at least _____ to 3 m/s to provide wind-chill cooling effect; above 35 degrees Celsius, heat stress causes significantly elevated mortality.

3.3.3 Broiler health and pre-slaughter management

Broiler health is managed through a combination of biosecurity, vaccination, and monitoring. Standard vaccination programme for Nigerian broilers: Newcastle disease (ND) vaccine at day 1 (spray), day 10 to 14 (eye-drop or drinking water), and sometimes day 21 to 24; Infectious Bursal Disease (Gumboro) vaccine at day 10 to 12 and day 21 to 24; Infectious Bronchitis (IB) vaccine where required. Marek's disease vaccine is administered at hatch. Coccidiosis is controlled by coccidiostats in the starter feed or live attenuated vaccine.

Pre-slaughter management: withdrawal of medicated feed (minimum 7-day withdrawal period before slaughter is required by regulations to avoid drug residues in meat); feed withdrawal 6 to 8 hours before slaughter to empty the gut and reduce carcass contamination during processing; catching and transport must be done at night or early morning to minimise heat stress and bruising. Bruising, broken wings, and death during transport are the major pre-slaughter losses in Nigerian broiler operations.

Fill in the blank: A minimum _____ -day feed withdrawal period is required before slaughter to ensure that medication residues are eliminated from the carcass before it enters the food chain.

Pilot questions 3.3

1. Describe how to prepare a house for broiler placement.
2. Explain how chick distribution under a brooder indicates thermal comfort or discomfort.
3. State three key grow-out management practices for commercial broilers.
4. List the standard vaccination programme for broilers in Nigeria.
5. Explain why feed withdrawal is required before slaughter and state the recommended duration.

3.4 Layer and Pullet Rearing Practices

3.4.1 Pullet rearing from day old to point of lay

Pullet rearing determines the future laying performance of the hen; a poorly reared pullet never fully compensates, regardless of subsequent management. Key targets: body weight at each age should match the breed standard (±10%); skeletal development should be complete by 10 to 12 weeks; plumage and immune system must be fully developed before the production phase. Pullets are reared under short daylength (8 to 10 hours) to delay sexual maturity and prevent small, early-lay eggs.

From day old to 6 weeks: chick starter diet; brooding management identical to broilers (33 to 35 degrees Celsius day 1); floor or cage rearing. Weeks 6 to 12: pullet grower diet; transition to final cage or floor system; beak trimming at 6 to 10 days of age (or infra-red beak treatment at hatch in modern operations) to prevent feather-pecking and cannibalism. Weeks 12 to 18: pullet developer diet (low calcium, moderate protein); daylength maintained short; final body weight and frame size achieved.

Fill in the blank: Pullets are reared under short daylength of _____ to 10 hours to delay sexual maturity and ensure body weight and skeletal development are complete before stimulation of lay.

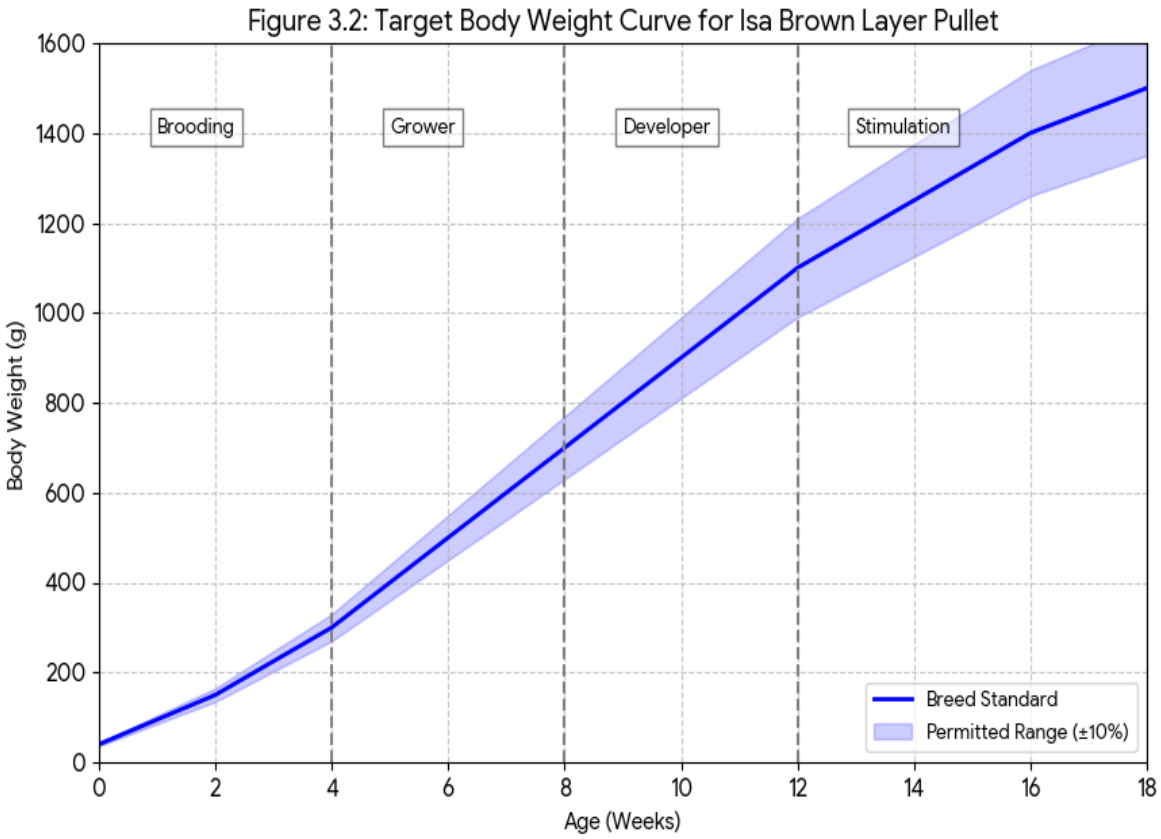

Figure 3.2: Graph showing target body weight curve for a commercial layer pullet from day old to point of lay

3.4.2 Layer management during the production period

At 18 to 19 weeks, daylength is increased to stimulate ovulation and egg production; the standard approach is a step-up from 10 hours to 16 hours over 4 weeks. Peak production (>90% HDP) is typically achieved by 26 to 28 weeks. After peak, production declines gradually (normal rate approximately 0.5% per week); by 72 weeks of age most commercial flocks are at 65 to 70% HDP and are depopulated for economic reasons. Daily management: collect eggs two to four times per day; record production and mortality; inspect birds for disease signs; check water and feed access.

Induced moulting extends the laying life by 12 to 16 months: at the end of the first cycle (around 72 weeks), birds are subjected to a controlled nutritional or hormonal stress that causes feather

loss and reproductive tract regression; after recovery (8 to 12 weeks), the second cycle begins with renewed production performance. Methods include low-sodium diets, feed withdrawal, or aluminium sulphate treatment. Induced moulting is practised widely in Nigeria to extend the productive life of expensive layer flocks.

Fill in the blank: Induced _____ is practised at the end of the first laying cycle to extend the productive life of commercial layers by 12 to 16 months; it involves a controlled nutritional or hormonal stress that causes feather loss and reproductive tract regression.

3.4.3 Turkey, duck, and guinea fowl rearing

Turkey rearing: turkeys are brooded at 37 degrees Celsius (higher than chickens because poults are more susceptible to cold); starter diet of 28% crude protein (higher than chicken); poults are prone to piling (crowding in corners and suffocating) and require careful brooding management. Commercial broad-breasted turkeys reach 6 to 8 kg (hens) and 12 to 16 kg (toms) at 16 to 22 weeks. Artificial insemination is required for all commercial turkey production.

Duck rearing: ducklings are brooded at 30 to 32 degrees Celsius; they need access to water but not swimming facilities during the first 2 weeks (wet litter and chilling are risks). Ducks can be raised on deep litter or in cages; they grow rapidly and reach 2.5 to 3 kg in 7 to 8 weeks. Guinea fowl rearing: keets (young guinea fowl) are brooded at 35 degrees Celsius; starter diet 25 to 26% CP; highly susceptible to dampness and Newcastle disease; typically finished at free range from 8 weeks; slaughter at 12 to 16 weeks.

Fill in the blank: Turkey poults are brooded at _____ degrees Celsius; this is higher than chickens because poults are more susceptible to cold and more likely to develop respiratory disease when chilled.

Species	Brooding Temperature	Starter Protein (%)	Production System	Slaughter Age	Slaughter Weight	Notes

Turkey	37 °C	28%	AI required	16–22 weeks	Hen: 6–8 kg; Tom: 12–16 kg	Requires strict biosecurity
Duck	30–32 °C	20–22%	No swimming water first 2 weeks	7–8 weeks	2.5–3 kg	Hardy, fast-growing
Guinea Fowl	35 °C	25–26%	Free range from 8 weeks	12–16 weeks	Variable	Susceptible to dampness and Newcastle disease

Box 3.2: Summary of rearing parameters for turkey, duck, and guinea fowl

Pilot questions 3.4

1. State four key targets in pullet rearing and explain why each matters.
2. Explain what induced moulting is and state two methods used to induce it.
3. Describe the management of layer hens during the production period, including daily tasks.
4. Compare brooding requirements for turkeys, ducks, and guinea fowl.
5. Explain why AI is required for commercial turkey production.

Series Summary

This Series covered breeding, nutrition, and rearing. Breeder management: body weight restriction (60-80% ad libitum) prevents obesity and maintains fertility; male-to-female ratio 1:8-10 for broilers; AI standard for turkeys. Breeder nutrition emphasises fat-soluble vitamins (A,

D3, E) and trace minerals for embryo quality. Poultry nutrition: energy (ME), protein (methionine first-limiting), minerals (Ca, P, Na), vitamins, and water. Maize and soyabean meal are the primary feed ingredients; formulation targets change by phase.

Broiler rearing: house prep (clean, disinfect, pre-warm); placement 10-15 birds/m2; brooding (33-35 degrees Celsius day 1, reduce 2-3 degrees/week); grow-out (weekly weighing, litter management, ventilation); vaccination (ND, Gumboro, IB, Marek's, coccidiosis); 7-day drug withdrawal; 6-8 hour feed withdrawal pre-slaughter. Layer management: pullet rearing (short daylength 8-10 hours; body weight targets; beak trimming at 6-10 days); stimulation at 18-19 weeks; peak HDP 90% at 26-28 weeks; induced moulting at 72 weeks. Turkey (37 degrees Celsius brooding; 28% CP; AI required); duck (30-32 degrees Celsius); guinea fowl (35 degrees Celsius; susceptible to dampness). By completing this Series, you should achieve all seven SLOs (3.1 to 3.7).

Glossary of Terms

- **Ad libitum feeding:** feed available at all times; birds eat as much as they want; standard for broilers and most layer phases except the restricted phase.
- **Beak trimming:** removal of one-third of the upper beak (and sometimes lower beak) at 6-10 days of age to prevent feather-pecking and cannibalism in laying flocks.
- **Body weight restriction:** providing breeders with only 60-80% of ad libitum feed intake to control body weight and maintain fertility and leg soundness.
- **Breeder flock:** a flock of sexually mature males and females maintained to produce fertile hatching eggs for a hatchery.
- **Brooding:** provision of supplementary heat for young chicks or poults in the first 1-3 weeks of life when thermoregulation is incomplete.
- **Coccidia/coccidiosis:** protozoan intestinal parasites (Eimeria spp.) causing bloody diarrhoea and mortality; controlled by coccidiostats in feed or live vaccine.

- **Controlled feeding:** providing a set measured quantity of feed per bird per day, rather than ad libitum; used for breeders and pullets to manage body weight.
- **Feed withdrawal:** withholding feed for 6-8 hours before slaughter to empty the gut and reduce carcass contamination; and 7 days before slaughter for drug residue clearance.
- **Gumboro disease (IBD):** Infectious Bursal Disease; a viral disease causing immunosuppression in young chickens; vaccine administered at day 10-12 and 21-24.
- **Induced moulting:** a controlled nutritional or hormonal stress applied at the end of the first laying cycle to cause feather loss and reproductive tract regression, followed by a second laying cycle.
- **Keet:** a young guinea fowl.
- **Metabolisable energy (ME):** energy available to the bird after subtracting digestive and urinary losses; expressed in kcal/kg or MJ/kg; the standard energy measure in poultry nutrition.
- **Methionine:** the first-limiting essential amino acid in maize-soyabean poultry diets; deficiency reduces growth and egg production; supplemented as DL-methionine.
- **Newcastle disease (ND):** a highly contagious viral disease of poultry; one of the most important diseases in Nigerian poultry; managed by vaccination at day 1, 10-14, and 21-24.
- **Perosis:** slipped tendon disease in poultry; caused by manganese or biotin deficiency in breeder diets; the tendon slips off the hock joint, causing permanent lameness.
- **Point of lay:** the age at which a pullet begins egg production; commercial layer hybrids reach point of lay at 18-19 weeks.
- **Poult:** a young turkey.
- **Skip-a-day feeding:** a breeder management practice in which feed is provided every other day to control body weight while allowing birds to eat a full day's ration on feeding days.

- **Withdrawal period:** the minimum number of days (7 days for most veterinary medicines) between the last medication dose and slaughter, required to ensure residues are cleared from the carcass.

Concept Check Questions [Series 3]

Objective Questions

1. Broiler breeders are fed on a restricted programme providing 60 to _____ per cent of ad libitum intake to maintain fertility and body condition. (Linked to SLO 3.1)
2. _____ is the first-limiting amino acid in maize-soyabean poultry diets; its deficiency reduces growth rate and egg production. (Linked to SLO 3.2)
3. Broiler chicks _____ under the brooder indicate the temperature is too cold; chicks at the edges indicate too much heat. (Linked to SLO 3.4)
4. Pullets are reared under short daylength of 8 to _____ hours to delay sexual maturity until body weight and skeletal development are complete. (Linked to SLO 3.5)
5. A minimum _____ -day drug withdrawal period is required before slaughter to clear medication residues from the broiler carcass. (Linked to SLO 3.4)

Short-Answer Questions

- Explain why breeder body weight control is critical and describe the method used. (Linked to SLO 3.1)
- Name three energy and three protein ingredients used in Nigerian poultry feeds. (Linked to SLO 3.3)
- Describe the three broiler feeding phases and state the protein level in each. (Linked to SLO 3.3)
- State four daily management tasks for a commercial layer flock. (Linked to SLO 3.6)

- Compare turkey, duck, and guinea fowl brooding temperatures and starter protein requirements. (Linked to SLO 3.7)

Long-Answer Questions

1. Describe breeder flock management, natural mating, AI, and the nutritional requirements of breeder diets. (Linked to SLOs 3.1)
2. Describe the nutrient requirements of poultry, major feed ingredients, and feeding programmes for broilers and layers. (Linked to SLOs 3.2, 3.3)
3. Describe broiler rearing from placement through pre-slaughter management, and describe pullet rearing from day old to point of lay and layer management. (Linked to SLOs 3.4, 3.5, 3.6)

Answers to Concept Check Questions [Series 3]

Objective Questions

6. 80.
7. Methionine.
8. Huddle.
9. 10.
10. 7.

Short-Answer Questions

11. Overweight broiler breeder females have reduced fertility, lower egg production, and leg problems. Feed restriction at 60-80% of ad libitum intake controls body weight. Skip-a-

day feeding is also used: feed is provided every other day to control weight while maintaining bird satisfaction.

12. Energy: maize (primary, 8.5-9.0 MJ ME/kg), sorghum, wheat offals. Protein: soyabean meal (44-48% CP, primary protein source), groundnut cake (45% CP), fish meal (65% CP).
13. Starter (day 1-10): 22-24% CP; crumble/small pellet; high protein for rapid early growth. Grower (day 11-28): 20-22% CP; pellet; protein reduced as skeletal growth slows. Finisher (day 29-slaughter): 18-20% CP; pellet; protein further reduced; withdrawal diet if applicable.
14. Collect eggs 2-4 times per day; record daily egg production and HDP; record daily mortality and remove dead birds; inspect birds for disease signs; check feed and water access and consumption.
15. Turkey: 37 degrees Celsius; 28% CP. Duck: 30-32 degrees Celsius; 20-22% CP. Guinea fowl: 35 degrees Celsius; 25-26% CP.

Long-Answer Questions

1. Breeder flock: sexually mature males and females producing fertile hatching eggs; floor system for broiler breeders; nest boxes (1 per 5-6 hens); body weight restriction (60-80% ad libitum or skip-a-day) prevents obesity, infertility, and leg problems. Natural mating: male-to-female ratio 1:8-10 for broilers; 1:10-12 for turkeys; 1:10-15 for layers; males selected for BW, conformation, libido, sperm quality. AI: standard for commercial turkeys (too heavy for natural mating); semen collected by abdominal massage; diluted with saline extender; inseminated every 10-14 days; also used in layer breeding for parentage control. Breeder nutrition: protein and lysine for egg albumen; Ca 3.0-3.5% and P for shell; vitamin A and E for fertility and embryo development (vitamin E critical for spermatogenesis); vitamin D3 for Ca metabolism; selenium and zinc for sperm quality; manganese deficiency causes perosis in chicks. Breeder diet differs from layer diet in vitamin and mineral concentrations to ensure well-nourished hatching eggs.

2. Nutrient requirements: energy (ME kcal/kg; birds eat to energy need); protein and amino acids (lysine, methionine first-limiting, threonine, tryptophan); minerals (Ca 2-4% depending on phase, available P 0.35-0.45%, NaCl 0.15-0.20%, trace minerals); vitamins (fat-soluble A, D3, E, K; water-soluble B-complex); water (most critical; 10% reduction causes 10% fall in egg production). Feed ingredients: energy (maize primary 8.5-9.0 MJ ME; sorghum; wheat offals; rice bran); protein (soyabean meal 44-48% CP primary; groundnut cake 45% CP; fish meal 65% CP); minerals (DCP or bone meal; limestone/oyster shell; salt; vitamin-mineral premix). Formulation: least-cost linear programming; Pearson square for simple balancing. Feeding programmes: broilers — starter (day 1-10; 22-24% CP; crumble); grower (11-28; 20-22%; pellet); finisher (29+; 18-20%; pellet; withdrawal if medicated). Layers: chick starter (0-6 weeks); grower (6-12 weeks); developer (12-18 weeks; low calcium deliberately); layer diet (18 weeks+; Ca 3.5-4.0%; controlled amounts prevent obesity). Pelleting improves FCR 5-10% over mash.
3. Broiler placement: clean, disinfect, rest house 2 weeks; spread litter 5-8 cm; set equipment; pre-warm to 33-35 degrees Celsius 24 hours before arrival; place 10-15 birds/m2; provide water immediately. Brooding: monitor chick distribution (huddled = cold; spread to edges = hot; even = correct); reduce temperature 2-3 degrees/week; adjust drinker height daily; observe twice daily. Grow-out: weekly 5% body weight sample vs breed standard; daily feed/water recording; litter management (dry, friable; remove wet patches); thin out at 28-35 days; ventilation ≥2-3 m/s; temperature ≤30 degrees Celsius. Health: ND vaccine day 1, day 10-14, day 21-24; Gumboro day 10-12 and 21-24; IB where required; Marek's at hatch; coccidiostats in starter feed or vaccine. Pre-slaughter: 7-day drug withdrawal; 6-8 hour feed withdrawal; catch and transport at night/morning to minimise heat stress and bruising. Pullet rearing: body weight at breed standard (±10%); short daylength 8-10 hours; chick starter 0-6 weeks; beak trim at 6-10 days; grower 6-12 weeks; developer 12-18 weeks (low Ca, short day); stimulate lay at 18-19 weeks (step daylength to 16 hours). Layer production: peak HDP >90% at 26-28 weeks; decline ≈0.5%/week; daily tasks (egg collection 2-4x, production and mortality records, bird inspection, feed and water check); induced moulting at 72 weeks (low-Na diet, feed withdrawal, or Al2SO4) for second laying cycle.

Answers to Pilot Questions [Series 3]

Part 3.1

6. Broiler breeder females have a strong genetic drive to overeat because they were derived from fast-growing meat breeds; unlimited feed causes them to become obese. Obese breeders have reduced ovulation rates and fertility, lower egg numbers, leg and joint problems (because heavy bodyweight strains the skeletal system), and higher mortality. Feed restriction at 60-80% of ad libitum intake keeps body weight at the breed target, maintaining fertility, production, and longevity.
7. Broiler breeders (floor mating): 1 male per 8-10 females; too few males means some hens go unmated and eggs are infertile; too many males causes over-mating injury to hens. Turkeys (natural mating): 1 tom per 10-12 hens; toms are aggressive and broad-breasted commercial birds struggle to mount effectively at heavier weights, limiting the ratio.
8. Commercial broad-breasted tom turkeys are selected for extremely rapid muscle growth and wide breast development; this selection has resulted in body conformations in which the males cannot mount hens effectively for natural mating without injuring the hen or failing to achieve intromission. Fertility rates under natural mating in heavy commercial lines fall below 50-60%; AI raises fertility to 80-90%. Semen is collected by abdominal massage and milking the phallus, diluted in a saline extender, and inseminated into the hen oviduct every 10-14 days.
9. Vitamin E: critical for spermatogenesis in males (deficiency reduces sperm motility and count) and for embryo development (deficiency causes early embryo mortality); selenium works synergistically with vitamin E. Calcium (3.0-3.5% of diet): required for eggshell formation; inadequate calcium causes thin, porous shells that are damaged during nest collection and have poor hatchability. Vitamin A: essential for mucosal integrity of the reproductive tract; deficiency causes reduced fertility and increased embryo mortality in both sexes.
10. Perosis is a permanent lameness condition in young chicks and poults in which the gastrocnemius tendon (Achilles tendon) slips laterally off the hock joint; the hock twists

outward and the bird cannot walk normally. It is caused by manganese deficiency in the breeder diet: the developing embryo requires manganese for normal cartilage and tendon development in the hock joint; when the breeder diet is deficient, the hatched chick has insufficient manganese stored in the egg for normal joint development, regardless of what the chick itself eats after hatch.

Part 3.2

11. Energy (from carbohydrates and fats): primary driver of feed intake; provides ATP for all metabolic processes. Protein (amino acids): growth, tissue repair, enzyme and hormone synthesis, egg albumen. Minerals (Ca, P, Mg, Na, trace minerals): bone structure, eggshell, enzyme cofactors, electrolyte balance. Vitamins (A, D3, E, K, B-complex): metabolic regulation, immune function, reproduction, Ca metabolism. Water: solvent for all reactions; transport of nutrients; thermoregulation; most critical nutrient. Fats: concentrated energy (2.25x carbohydrates per gram); carrier of fat-soluble vitamins; essential fatty acids for membrane integrity.
12. Methionine is described as first-limiting because: in the most common Nigerian poultry diet (maize + soyabean meal), the ratio of available methionine to the bird's requirement is lower than for any other essential amino acid; all other amino acids are present in relatively adequate amounts relative to requirement. When the diet is deficient in methionine, protein synthesis stops at the rate allowed by methionine supply regardless of how much of the other amino acids are present. Adding synthetic DL-methionine to a maize-soyabean diet raises overall protein utilisation more than adding any other single amino acid supplement.
13. Energy ingredients: maize (primary energy source; 8.5-9.0 MJ ME/kg); sorghum (similar energy to maize; used where maize is expensive or unavailable); wheat offals/bran (lower energy; used at 5-15% to reduce diet cost). Protein ingredients: soyabean meal (44-48% CP; primary protein; well-balanced amino acid profile); groundnut cake (45% CP; widely available in northern Nigeria; risk of aflatoxin contamination requires testing); fish meal (65% CP; highly digestible; expensive; used at 2-5% to boost amino acid quality).

14. Starter (day 1-10): 22-24% crude protein; small crumble or mash form; high protein to support rapid early skeletal and organ development; high lysine and methionine. Grower (day 11-28): 20-22% CP; pellet form; protein reduced as the proportion of muscle to bone development shifts; energy concentration maintained or slightly increased. Finisher (day 29-slaughter): 18-20% CP; pellet; protein further reduced; energy increased to maximise fat deposition and final weight; if medicated feeds have been used, a withdrawal diet free of coccidiostats is used in the final 5-7 days.
15. The pullet developer diet (12-18 weeks) deliberately contains low calcium (0.9-1.0% Ca) for two reasons: (1) the reproductive tract is not yet mature and cannot yet mobilise calcium efficiently for eggshell production; high dietary calcium at this stage causes premature calcium deposition in the medullary bone before the oviduct is ready to use it, reducing the bird's subsequent calcium mobilisation capacity during actual egg production; (2) keeping calcium low prevents stimulation of the calcium absorption mechanisms before point of lay, preserving peak capacity for the production phase when it is actually needed.

Part 3.3

1. House preparation: (1) remove all litter, manure, and organic material completely; (2) dismantle and remove all moveable equipment (feeders, drinkers, brooders); (3) high-pressure wash all surfaces (floor, walls, ceiling, equipment); (4) apply disinfectant at correct dilution; (5) allow minimum 48-hour contact time and 2-week rest period; (6) replace and spread fresh litter (wood shavings or rice husks) 5-8 cm deep; (7) reinstall and fill feeders and drinkers; (8) light brooders 24 hours before chick arrival to pre-warm the house to 33-35 degrees Celsius at chick level.
2. Correct temperature: chicks distribute evenly throughout the brooding area, move freely, are active, and are heard vocalising contentedly. Too cold: chicks huddle tightly under or directly beneath the brooder heat source, pile on top of each other (risk of suffocation), and emit a loud continuous distress chirping. Too hot: chicks move as far as possible from the brooder to the edges and corners of the house; they pant (open-beak breathing),

drink excessively, and may lie flat on the litter. Management response: cold — lower brooder closer to chicks or increase gas supply; hot — raise brooder or reduce gas.

3. Three key grow-out practices: (1) weekly body weight sampling (weigh 5% of flock; calculate mean and coefficient of variation; compare against breed standard; CV >10% triggers investigation of feed access, disease, or sorting problems); (2) litter management (inspect litter daily; remove wet, caked patches immediately; adjust ventilation to maintain dry, friable litter; wet litter causes foot pad dermatitis, respiratory disease, and ammonia stress); (3) ventilation management (maintain minimum 2-3 m/s air speed in tunnel houses; ensure house temperature does not exceed 30 degrees Celsius; high temperature is the leading cause of elevated mortality in Nigerian broiler grow-out).
4. Standard Nigerian broiler vaccination programme: Marek's disease — in ovo on day 18 or subcutaneously at hatch; Newcastle disease (ND) — day 1 spray at hatchery, day 10-14 eye-drop or drinking water, day 21-24 drinking water (in high-challenge areas); Infectious Bursal Disease (Gumboro) — day 10-12 drinking water, day 21-24 drinking water; Infectious Bronchitis (IB) — day 1 spray where required (combined with ND); Coccidiosis — live attenuated oocyst vaccine in drinking water at day 5-7, or continuous coccidiostat in starter feed.
5. Feed withdrawal is required for two distinct purposes: (1) Drug residue clearance: a minimum 7-day withdrawal period between the last dose of any medicated feed (containing antibiotics, coccidiostats, or other drugs) and slaughter is required by food safety regulations to ensure that drug residues in muscle, liver, kidney, and eggs fall below the maximum residue limit (MRL) before the carcass enters the food chain; violation can result in export rejection and prosecution. (2) Gut clearance before slaughter: feed is withheld for 6-8 hours immediately before slaughter to empty the gastrointestinal tract; an empty gut reduces the risk of intestinal rupture during evisceration and faecal contamination of the carcass at the processing plant.

Part 3.4

1. Four key pullet rearing targets: (1) body weight at breed standard (±10%) at each weekly weigh point — underweight pullets have reduced laying potential; overweight pullets have delayed, poor-quality production; (2) skeletal development complete by 10-12 weeks — the skeleton must be fully mineralised before production begins so that bone calcium can be mobilised for shell formation; (3) immune system fully developed — all vaccinations completed before production phase begins; (4) plumage complete — full feather coverage is required for thermal regulation during production.
2. Induced moulting is a management technique applied at the end of the first laying cycle (around 72 weeks) to cause the reproductive system to regress and then regenerate, allowing a second production cycle of 12-16 months. Two methods: (1) Low-sodium (low-salt) diet: the layer diet is replaced with a low-sodium diet for 3-4 weeks; sodium deprivation causes appetite suppression, weight loss, feather loss, and ovarian regression; after restoration of normal diet, production resumes; this method is considered more humane than complete feed withdrawal. (2) Feed withdrawal: all feed is withheld for 5-10 days (method less used due to welfare concerns in some countries); causes rapid body weight loss and feather loss followed by reproductive regression and renewal.
3. Daily management tasks during production: (1) egg collection 2-4 times per day (frequent collection reduces dirty eggs, cracked eggs, and floor egg problems; very important in hot weather when egg quality deteriorates faster); (2) record daily egg production per house and calculate HDP (hen day production); any drop of >3% HDP in one day triggers investigation for disease, water failure, feed quality problem, or heat stress; (3) record daily mortality (remove dead birds immediately to prevent disease spread and cannibalism); (4) inspect birds visually for disease signs (runny nose, swollen sinuses, abnormal droppings, lameness); (5) check feed and water delivery (blocked nipples or empty troughs reduce intake and production same day).
4. Turkey: brooding temperature 37 degrees Celsius (highest of the three species; poults are very susceptible to chilling and respiratory disease when cold); starter crude protein 28% (highest because turkey growth is very rapid and muscle development is extreme); poults prone to piling (crowding in corners under stress) requiring careful house design and management. Duck: brooding temperature 30-32 degrees Celsius (lower than chickens; ducklings are slightly more cold-hardy); starter CP 20-22%; avoid swimming water for

first 2 weeks (ducklings lose maternal oil coat and chill rapidly in standing water). Guinea fowl: brooding temperature 35 degrees Celsius; starter CP 25-26%; highly susceptible to dampness and Newcastle disease; free-range from 8 weeks.

5. Commercial broad-breasted turkey breeds are selected for extreme breast muscle development; the hypertrophied breast muscles prevent toms from mounting hens effectively (the tom cannot position his cloaca close enough to the hen's cloaca for sperm transfer); fertility rates under natural mating in commercial broad-breasted lines fall to 40-60%. AI allows commercial turkey production to achieve 80-90% fertility: semen is collected from toms by abdominal massage and milking of the phallus, diluted in an extender medium to increase volume, and inseminated into each hen by inserting a syringe with a smooth cannula into the oviduct 5-6 cm, then slowly ejecting the semen while withdrawing; hens are inseminated every 10-14 days throughout the hatching egg collection period.

References and Attributions [Series 3]

Textual References (Books and External Sources)

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4. FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.

Figures, Plates, Tables, and Boxes

1. Figure 3.1: Broiler chick thermal comfort distribution photograph Attribution: AI generated. Suggested OER search string: "broiler chick distribution thermal comfort cold correct hot brooding temperature OER photograph".
2. Box 3.1: Nutrient specifications for Nigerian poultry diets by phase Attribution: AI generated. Suggested OER search string: "poultry diet nutrient specifications broiler starter grower finisher layer Nigeria OER box".
3. Figure 3.2: Layer pullet body weight curve graph Attribution: AI generated. Suggested OER search string: "layer pullet body weight curve Isa Brown breed standard point of lay OER graph".
4. Box 3.2: Rearing parameters for turkey, duck, and guinea fowl Attribution: AI generated. Suggested OER search string: "turkey duck guinea fowl rearing parameters brooding temperature protein slaughter OER box".

Course code: AGE 406

Course title: Poultry Production Education

Series 4: Meat, Egg Production, and Carcass Quality

- **Part 4.1: Poultry Meat Production and Processing**
  - Sub Part 4.1.1: Broiler slaughter and processing steps
  - Sub Part 4.1.2: Carcass cuts and yield
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- **Part 4.2: Carcass Quality Assessment**
  - Sub Part 4.2.1: Factors affecting carcass quality
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- **Part 4.3: Egg Production and Quality**
  - Sub Part 4.3.1: Physiology of egg formation
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Introduction

Meat and eggs are the two primary outputs of the commercial poultry industry. Understanding how a live bird becomes a safe, marketable carcass, how carcass quality is assessed and graded, how eggs are formed and what determines their quality, and how eggs are handled and processed to meet market standards are essential skills for anyone managing or supplying the Nigerian poultry value chain.

This Series covers the complete broiler processing sequence, carcass cuts, meat quality, ante-mortem and post-mortem inspection, carcass grading, the physiology of egg formation, egg quality characteristics and their assessment, and egg handling, grading, and processing. These topics connect production management (Series 3) to marketing (Series 5).

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** describe the steps of broiler slaughter and processing and explain the purpose of each (Linked to Part 4.1),
- **SLO 4.2** identify the standard carcass cuts and calculate dressing percentage and cut yields (Linked to Part 4.1),
- **SLO 4.3** describe the characteristics used to assess poultry meat quality (Linked to Part 4.1),
- **SLO 4.4** describe the factors affecting carcass quality and explain ante-mortem and post-mortem inspection (Linked to Part 4.2),
- **SLO 4.5** describe the system for grading and classifying poultry carcasses (Linked to Part 4.2),
- **SLO 4.6** describe the physiology of egg formation and the components of the egg (Linked to Part 4.3),
- **SLO 4.7** describe egg quality characteristics and the factors that affect them (Linked to Part 4.3), and

- **SLO 4.8** describe egg collection, cleaning, grading, and processing into egg products (Linked to Part 4.4).

4.1 Poultry Meat Production and Processing

4.1.1 Broiler slaughter and processing steps

Commercial broiler processing follows a sequential series of steps. Catching and transport: birds caught at night to reduce stress; placed in transport crates; delivered to processing plant. Ante-mortem inspection: live birds inspected by a veterinarian or trained inspector before slaughter; diseased, injured, or moribund birds are condemned or separated. Stunning: birds are electrically stunned in a water bath (20 to 50 mA per bird) or by controlled atmosphere (CO_2) to render them unconscious before bleeding.

Bleeding: stunned birds are hung by the legs on a shackle line; the jugular vein and carotid artery are cut; bleed-out takes 90 to 120 seconds. Scalding: carcasses are immersed in hot water (52 to 56 degrees Celsius for 90 to 120 seconds for soft scald) to loosen feathers. De-feathering: rotating rubber-finger picker machines remove feathers. Evisceration: removal of head, feet, and viscera; vent is opened and organs removed. Chilling: carcasses immersed in ice water (below 4 degrees Celsius) or air-chilled to reduce temperature rapidly.

Fill in the blank: Scalding in hot water at 52 to 56 degrees Celsius for 90 to 120 seconds loosens feathers for _____; this step is followed by de-feathering with rotating rubber-finger picker machines.

4.1.2 Carcass cuts and yield

Dressing percentage (DP) is the carcass weight as a percentage of live body weight after removal of feathers, head, feet, and viscera. Standard DP for commercial broilers is 72 to 76% of live weight. The ready-to-cook (RTC) carcass is then cut into standard portions. Primary cuts: breast (with or without bone; the highest-value cut; 28 to 35% of RTC weight); whole leg (drumstick + thigh; 25 to 30% of RTC weight); back; wing (8 to 10% of RTC weight).

Further processing cuts: boneless skinless breast fillet (the highest-value cut per kg; 20 to 25% of RTC weight); drumstick alone (12 to 15% RTC weight); thigh (12 to 14% RTC weight); wing portions (drumette, wingette, wing tip). Giblets (liver, gizzard, heart) add approximately 4 to 5% to the carcass yield. Cut yields vary with breed, age, sex, nutrition, and slaughter weight; breast yield is the primary commercial selection criterion in broiler breeding.

Fill in the blank: The dressing percentage (DP) for commercial broilers is _____ to 76 per cent of live weight; the boneless skinless breast fillet is the highest-value cut, comprising 20 to 25 per cent of the ready-to-cook carcass weight.

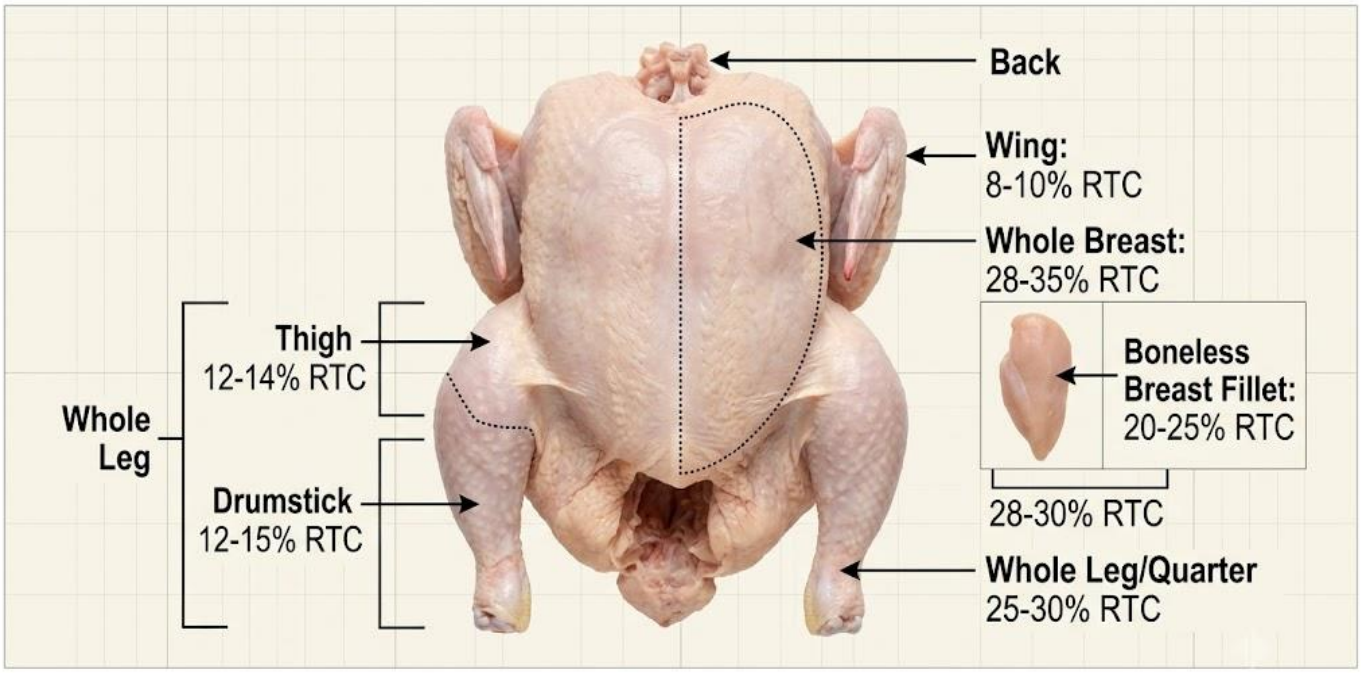

Figure 4.1: Diagram of standard poultry carcass cuts showing anatomical location and approximate yield of each portion

Figure 4.1: Diagram of standard poultry carcass cuts showing anatomical location and approximate yield of each portion

4.1.3 Meat quality characteristics

Key poultry meat quality characteristics: colour (breast muscle should be pale pink; dark coloured breast meat may indicate bruising, pale soft exudative (PSE) condition, or dark firm dry (DFD) meat; consumers prefer uniformly pale pink colour); tenderness (determined by muscle

fibre type, pH at rigor, chilling speed, and ageing/conditioning time post-slaughter; modern broilers are highly tender due to young slaughter age); juiciness (related to moisture retention and fat content of the meat).

pH: normal ultimate pH of poultry muscle is 5.7 to 6.0; PSE condition (pale, soft, exudative) occurs when pH falls too rapidly post-slaughter (ante-mortem stress causes glycogen depletion); DFD (dark, firm, dry) occurs when ultimate pH remains high (above 6.2) because glycogen was depleted before slaughter through chronic stress. Microbiological safety: total plate count, Salmonella absence, and Campylobacter control are the primary food safety criteria; chilling to below 4 degrees Celsius is the most important control measure.

Fill in the blank: PSE (pale, soft, _____) meat occurs when muscle pH falls too rapidly post-slaughter due to ante-mortem stress; DFD (dark, firm, dry) occurs when pH remains high due to chronic pre-slaughter stress.

Pilot questions 4.1

- List the steps of commercial broiler processing in the correct sequence.
- Define dressing percentage and state the normal range for commercial broilers.
- Name four standard carcass cuts and give the approximate yield of each as a percentage of RTC weight.
- Describe PSE and DFD meat defects and explain the conditions that cause each.
- Explain why rapid chilling after slaughter is critical for meat quality and food safety.

4.2 Carcass Quality Assessment

4.2.1 Factors affecting carcass quality

Pre-harvest factors: breed and genetics (breast yield and meat colour are highly heritable; broiler hybrids are selected for high breast yield); nutrition (protein and amino acid supply affects muscle development; vitamin E supplementation in the last 7 days before slaughter improves meat colour and oxidative stability; excess fat in the finisher increases carcass fat and reduces

lean yield); age and sex (older and heavier birds have higher dressing percentage but coarser muscle fibre; males grow faster than females but have lower breast yield at the same live weight).

Harvest and processing factors: catching and handling (rough handling causes bruising; bruising is a major cause of carcass downgrading and trim losses; catching at night when birds are calm reduces stress and bruising); transport duration and conditions (long transport distances, high temperature, and overcrowded crates increase mortality, weight loss, and ante-mortem stress; transport should not exceed 4 hours); stunning method (inadequate stunning leads to poor bleed-out, blood splashing, and PSE condition); scalding temperature (over-scalding damages skin and increases downgrade rate).

Fill in the blank: Rough catching and handling cause _____ which is a major cause of carcass downgrading; catching birds at night when they are calm significantly reduces bruising and pre-slaughter stress.

4.2.2 Ante-mortem and post-mortem inspection

Ante-mortem inspection is conducted by a veterinarian or authorised meat inspector on live birds at the processing plant before slaughter. The inspector examines birds for signs of infectious disease (Newcastle disease, avian influenza), systemic illness, tumours (Marek's disease lymphomas), injuries, and severe emaciation. Birds identified with notifiable diseases are condemned and the flock may be rejected entirely. Suspect birds are separated into a suspect pen for more careful individual examination.

Post-mortem inspection is performed on each carcass and its viscera immediately after evisceration. The inspector examines: skin (bruising, infections, tumours, discolouration); muscle (colour, texture, haemorrhage); viscera (liver for colour, size, lesions; spleen for enlargement; heart for pericarditis; lungs and air sacs for infection). Condemned carcasses or parts are placed in sealed condemnation containers and disposed of as biohazard waste. A condemnation record is maintained for each batch.

Fill in the blank: Post-mortem inspection examines the _____, muscle, skin, and viscera of each carcass; condemned parts are placed in sealed containers and disposed of as biohazard waste.

Figure 4.2: Veteritary inspected linrout for foot reot, or surdering a liing, mortem carcass on centain inspection or disease

Figure 4.2: Photograph of a post-mortem poultry carcass inspection line in a processing plant

4.2.3 Grading and classification of poultry carcasses

Poultry carcass grading assesses the overall commercial quality of the carcass. Standard grading factors: conformation (shape and symmetry; normal body shape without crooked keel bone or deformed limbs); fleshing (amount of meat cover over the breast bone, thighs, and drumsticks; adequate fleshing is the primary quality determinant); fat cover (uniform light fat layer under the skin; excessive fat reduces grade); and defects (bruising, skin tears, missing parts, discolouration).

In Nigeria, formal carcass grading is not universally applied; the market operates primarily on live weight price at the farm gate. In formal commercial processing, two or three grades are used: Grade A (no visible defects; excellent conformation and fleshing; normal fat cover); Grade B (minor defects; slight bruising or skin tear; acceptable fleshing); Grade C (significant defects; used for processed products rather than whole carcass sale). Substandard carcasses may be further processed into sausages, minced chicken, or chicken stock.

Fill in the blank: Grade _____ poultry carcasses have no visible defects, excellent conformation, and normal fat cover; Grade B has minor defects; Grade C is used for further processing into sausages or minced products.

Pilot questions 4.2

- State four pre-harvest factors that affect broiler carcass quality.
- Explain how rough catching affects carcass quality and how it is prevented.
- Describe ante-mortem inspection and state what conditions lead to condemnation.
- Describe post-mortem inspection and state what is examined.
- State the criteria for Grade A, B, and C poultry carcasses.

4.3 Egg Production and Quality

4.3.1 Physiology of egg formation

An egg is formed in approximately 25 to 26 hours in the reproductive tract of the hen. The ovary contains thousands of follicles; one follicle matures and ovulates approximately 30 minutes after the previous egg is laid. The ovulated yolk (oocyte) is caught by the infundibulum (the funnel-shaped opening of the oviduct); fertilisation by sperm (if present) occurs here. The yolk passes through the magnum (where albumen proteins are secreted; takes 3 hours) and the isthmus (where shell membranes are formed; 1 hour).

The egg then moves to the uterus (shell gland) where the shell is mineralised over approximately 20 hours; calcium carbonate is deposited on the outer shell membrane to form the shell; the

cuticle (a protein coating) is applied last. Finally, the egg passes through the vagina and is laid. A hen with a daylength of 16 hours can sustain one egg every 25 to 26 hours; the ovulation-to-lay cycle shifts slightly each day until the hen has a day off before the next sequence (clutch).

Fill in the blank: Shell mineralisation occurs in the _____ (shell gland) over approximately 20 hours; calcium carbonate is deposited on the outer shell membrane to form the hard shell.

4.3.2 Egg quality characteristics

External quality: shell quality (shell strength, thickness, texture, and freedom from cracks; thin shells crack easily during collection and transport; shell strength is measured by deformation or impact force; normal shell weight is 10 to 11% of total egg weight); shell colour (white or brown depending on breed; no effect on nutritional value or internal quality; consumer preference varies by market); egg weight (classified by size; commercial layer eggs range from 45 to 75 g; average 60 to 65 g).

Internal quality: albumen quality measured by Haugh Unit (HU): the height of the thick albumen relative to egg weight; fresh eggs have HU >72 (Grade AA); lower HU indicates loss of albumen gel structure due to age or heat; yolk index (ratio of yolk height to yolk diameter; fresh eggs 0.40 to 0.42; declines with age as the vitelline membrane weakens); blood spots and meat spots (inclusions from follicle haemorrhage or reproductive tract tissue; consumer rejections); air cell size (grows with age as moisture evaporates through the shell).

Fill in the blank: The Haugh Unit (HU) measures albumen _____ relative to egg weight; fresh eggs have HU >72; lower values indicate deterioration of albumen gel structure due to ageing or heat.

Grade	External Characteristics	Internal Characteristics
Grade AA	Clean, uncracked, normal shape; shell strength >34 N; Haugh Unit (HU) >72; small air cell <3 mm	Clear thick albumen; yolk well-centred and firm; no blood or meat spots
Grade A	Clean, uncracked; HU 60–72; air cell 3–6 mm	Clear albumen, slightly watery; yolk slightly flat; no blood spots

Grade B	Slight stains permitted; HU <60; larger air cell	Watery albumen; flat yolk; small blood or meat spots permitted

Box 4.1: Summary of egg quality grading criteria by internal and external characteristics

4.3.3 Factors affecting egg quality

Genetic factors: breed and strain strongly influence shell colour, egg size, and shell thickness; certain lines are selected for improved shell strength. Nutritional factors: calcium deficiency causes thin, soft shells; phosphorus imbalance disrupts Ca absorption; vitamin D3 deficiency impairs shell mineralisation; vitamin E and selenium protect yolk membranes from oxidation (yolk colour is determined by xanthophyll pigments in the diet; marigold meal or paprika added to feed deepens yellow yolk colour to match consumer preference).

Age of the hen: shell quality decreases progressively with age as the hen's calcium metabolism efficiency declines; older hens lay larger eggs with proportionally thinner shells. Disease: Newcastle disease and Infectious Bronchitis (IB) are the most common causes of sudden egg quality decline (soft-shelled or shell-less eggs, abnormal yolk, watery albumen). Storage conditions: internal quality declines rapidly at ambient temperature; a fresh egg stored at 30 degrees Celsius loses the equivalent of 7 days of quality compared with one stored at 12 degrees Celsius.

Fill in the blank: Infectious _____ (IB) virus is a major cause of sudden egg quality problems including soft-shelled or shell-less eggs, abnormal yolk colour, and watery albumen in laying flocks.

Pilot questions 4.3

1. Describe the passage of an egg through the oviduct, naming each section and stating what happens there.
2. Define the Haugh Unit and explain what it measures.
3. State four factors that affect eggshell quality.
4. Explain how storage temperature affects internal egg quality.

5. Explain how yolk colour is determined and how producers can deepen yolk colour.

4.4 Egg Handling, Processing, and Grading

4.4.1 Egg collection, cleaning, and storage

Eggs should be collected from the laying house 2 to 4 times per day; frequent collection reduces the time eggs spend at ambient temperature (quality declines rapidly at 30 to 35 degrees Celsius in Nigeria); it also reduces the number of dirty, cracked, and floor eggs. Collected eggs are placed in clean plastic or foam trays (30 eggs per tray) with the blunt end up (to maintain air cell position). Dirty eggs are set aside; cracked eggs are separated for immediate sale or processing.

Dry cleaning (dry wiping with a clean cloth or fine sandpaper) is preferred over wet washing because the shell cuticle (protective protein coating) is water-soluble and washing removes it, increasing microbial penetration. If washing is necessary, water must be warmer than the egg (10 degrees Celsius above egg temperature) to prevent bacterial suction into the pores by the temperature differential. Eggs should be stored at 12 to 15 degrees Celsius and 70 to 80% RH; in Nigeria, refrigerated egg storage dramatically extends shelf life from 3 to 5 days (ambient) to 4 to 6 weeks.

Fill in the blank: Dry cleaning is preferred over _____ washing because washing removes the protective shell cuticle, increasing bacterial penetration through the shell pores.

4.4.2 Egg grading and quality standards

Commercial egg grading sorts eggs by size (weight) and quality (external and internal examination). Size grades: extra large (>68 g); large (60 to 68 g); medium (53 to 60 g); small (45 to 53 g); peewee (<45 g). Quality grades (see Box 4.1 for details): Grade AA (premium; fresh, uncracked, clear albumen, firm yolk, HU >72, air cell <3 mm); Grade A (standard commercial; HU 60 to 72); Grade B (second quality; for processing). In Nigeria, formal grading is primarily practised by supermarkets and export-oriented producers.

Grading equipment: manual grading uses a candling lamp (to detect blood spots, meat spots, cracks, and air cell size) and a scale; automated egg grading machines (Moba, Sanovo) combine weighing, candling, crack detection, and dirt detection on a high-speed automated line. Graded eggs are stamped with a production date, farm code, and grade, then packed into retail cartons (6, 12, or 30 eggs). In Nigeria, most eggs reach the consumer in open trays without formal grading or date-stamping.

Fill in the blank: Grade AA eggs must have Haugh Unit >72 and air cell depth <_____ mm; they are classified as premium quality suitable for direct retail sale.

Figure 4.3: Photograph of a commercial egg grading and packing line

4.4.3 Egg products and value addition

Whole liquid egg: breaking, separating white from yolk, pasteurising, and packaging as liquid whole egg, liquid albumen, or liquid yolk; used by bakeries, food manufacturers, and catering

operations; extends shelf life and eliminates the need for shell handling. Dried egg products: spray-dried whole egg powder, albumen powder, and yolk powder; long shelf life (12 to 24 months); used in food manufacturing, infant formula, and pharmaceutical industries; not common in Nigeria but growing as the food processing sector develops.

Egg value addition for the Nigerian market: hard-boiled eggs in brine (marketed by roadside traders and fast food chains); scotch eggs (hard-boiled egg coated in minced meat, then fried; common at roadside stalls); egg rolls (boiled egg encased in pastry, fried; popular in Lagos and other cities); pickled eggs; flavoured omelettes and egg-based sauces for food service. These products create additional income opportunities and extend the market for Nigerian egg producers beyond the fresh table egg.

Fill in the blank: Spray-dried whole egg powder has a shelf life of 12 to _____ months; it is used in food manufacturing, infant formula, and pharmaceutical products where shell handling is impractical.

Product	Description	Market Applications
Liquid Whole Egg (pasteurised)	Processed, pasteurised liquid egg	Bakeries, hotels, caterers
Liquid Albumen	Egg white separated and pasteurised	Meringue, angel food cake, pharmaceutical manufacturing
Spray-Dried Whole Egg Powder	Powdered whole egg via spray drying	Infant formula, instant food manufacturing, pharmaceutical excipients
Hard-Boiled Eggs in Brine	Cooked eggs preserved in brine solution	Roadside trading, fast food chains, school lunch programmes
Scotch Eggs and Egg Rolls	Eggs wrapped in meat or pastry	Street food market, supermarket snack sections
Pickled Eggs	Eggs preserved in vinegar brine	Bar snacks, roadside marketing
Egg-Based Ready Meals	Convenience meals with egg as core ingredient	Emerging urban convenience food segment

Box 4.2: Egg value-added products and their market applications in Nigeria

Pilot questions 4.4

1. State why frequent egg collection is important in Nigerian conditions.
2. Explain why dry cleaning is preferred over wet washing of eggs.
3. Describe the size grades used for commercial egg classification.
4. Explain how automated egg grading machines work.
5. Name four egg products and state the market application of each in Nigeria.

Series Summary

This Series covered meat production, carcass quality, egg production, and egg grading. Broiler processing sequence: catching and transport, ante-mortem inspection, stunning, bleeding, scalding, de-feathering, evisceration, and chilling. Dressing percentage is 72 to 76%; primary cuts include breast (28-35%), whole leg (25-30%), and wings (8-10%). Meat quality defects (PSE and DFD) are caused by pre-slaughter stress affecting muscle pH. Carcass quality is affected by genetics, nutrition, handling, transport, stunning, and scalding.

Ante-mortem inspection screens live birds; post-mortem inspection examines each carcass and viscera. Grading: Grade A (no defects), Grade B (minor defects), Grade C (further processing). Egg formation takes 25 to 26 hours; the shell forms in the uterus over 20 hours. Quality is assessed by HU (>72 Grade AA), shell strength, air cell size, and yolk index. Factors affecting quality include nutrition, hen age, disease (IB, ND), and storage temperature. Egg handling: collect 2 to 4 times daily; dry clean; store at 12 to 15 degrees Celsius. Grading by size and quality; value-added products (liquid egg, dried powder, scotch eggs, egg rolls). By completing this Series, you should achieve all eight SLOs (4.1 to 4.8).

Glossary of Terms

1. **Air cell:** the gas-filled space at the blunt end of the egg, formed as the egg cools after laying and moisture evaporates; grows in size as the egg ages.
2. **Ante-mortem inspection:** examination of live poultry at the processing plant by a veterinarian or authorised inspector before slaughter.
3. **Condemnation:** the official rejection of a carcass, part of a carcass, or an organ as unfit for human consumption following inspection.
4. **Cuticle:** a thin protein coating applied to the outer surface of the eggshell just before laying; it is protective but water-soluble and is removed by wet washing.
5. **Dark firm dry (DFD):** a meat quality defect characterised by abnormally high ultimate pH (>6.2) and dark colour; caused by glycogen depletion through chronic pre-slaughter stress.
6. **Dressing percentage (DP):** carcass weight after removal of feathers, head, feet, and viscera as a percentage of live body weight; normal range 72-76% for broilers.
7. **Evisceration:** removal of the viscera (internal organs) from the carcass during processing.
8. **Follicle:** a developing ovum surrounded by granulosa cells in the hen's ovary; the largest follicle ovulates each day to begin egg formation.
9. **Giblets:** the edible internal organs of poultry (liver, gizzard, heart) included with the dressed carcass; approximately 4-5% of RTC weight.
10. **Grade A:** the highest commercial carcass and egg grade; no visible defects, excellent fleshing, normal shell, HU >72 for eggs.
11. **Haugh Unit (HU):** a measure of albumen quality calculated from albumen height and egg weight; fresh eggs have HU >72; declines with age and heat exposure.
12. **Infundibulum:** the funnel-shaped opening of the oviduct that catches the ovulated yolk; the site of fertilisation if sperm are present.

13. **Isthmus:** the section of the oviduct where the inner and outer shell membranes are formed around the developing egg.

14. **Magnum:** the longest section of the oviduct where albumen proteins (primarily ovomucin, ovalbumin, and ovotransferrin) are secreted around the yolk.

15. **Pale soft exudative (PSE):** a meat quality defect characterised by abnormally low ultimate pH (<5.5), pale colour, and high moisture loss; caused by rapid pH drop from ante-mortem stress.

16. **Post-mortem inspection:** examination of each carcass and its viscera immediately after evisceration by a meat inspector to detect disease, contamination, or quality defects.

17. **Ready-to-cook (RTC) weight:** carcass weight after removal of feathers, head, feet, and viscera but with giblets included; the standard weight for portion yield calculations.

18. **Scalding:** immersion of a slaughtered carcass in hot water (52-56 degrees Celsius) to loosen feather follicles before mechanical de-feathering.

19. **Stunning:** rendering a bird unconscious before slaughter using electrical current (water bath stunner) or controlled atmosphere (CO_2); required for humane slaughter.

20. **Uterus (shell gland):** the section of the oviduct where calcium carbonate is deposited over approximately 20 hours to form the hard eggshell.

21. **Yolk index:** the ratio of yolk height to yolk diameter; a measure of vitelline membrane integrity; fresh eggs 0.40-0.42; declines with age.

Concept Check Questions [Series 4]

Objective Questions

1. The dressing percentage for commercial broilers is _____ to 76 per cent of live weight. (Linked to SLO 4.2)

2. PSE (pale, soft, exudative) meat occurs when muscle pH falls too rapidly after slaughter due to _____ stress. (Linked to SLO 4.3)
3. Post-mortem inspection examines the carcass skin, muscle, and _____ of each bird immediately after evisceration. (Linked to SLO 4.4)
4. The Haugh Unit measures albumen _____ relative to egg weight; fresh Grade AA eggs have HU >72. (Linked to SLO 4.7)
5. Dry cleaning is preferred over wet washing because washing removes the protective shell _____, increasing bacterial penetration. (Linked to SLO 4.8)

Short-Answer Questions

- List the steps of broiler processing in the correct order. (Linked to SLO 4.1)
- Distinguish between PSE and DFD meat defects. (Linked to SLO 4.3)
- State the grading criteria for Grade A and Grade B poultry carcasses. (Linked to SLO 4.5)
- Describe the passage of the egg through the oviduct, naming each section. (Linked to SLO 4.6)
- State four factors that affect eggshell quality. (Linked to SLO 4.7)

Long-Answer Questions

1. Describe the broiler slaughter and processing sequence, the standard carcass cuts and yields, and the key meat quality characteristics. (Linked to SLOs 4.1, 4.2, 4.3)
2. Describe the factors affecting carcass quality, ante-mortem and post-mortem inspection, and the system of carcass grading. (Linked to SLOs 4.4, 4.5)
3. Describe egg formation physiology, egg quality characteristics and factors affecting them, and egg collection, grading, and processing. (Linked to SLOs 4.6, 4.7, 4.8)

Answers to Concept Check Questions [Series 4]

Objective Questions

6. 72.
7. Ante-mortem.
8. Viscera.
9. Height.
10. Cuticle.

Short-Answer Questions

11. Catching and transport → ante-mortem inspection → stunning → bleeding → scalding → de-feathering → evisceration → chilling.
12. PSE: pale, soft, exudative; caused by rapid pH drop after slaughter due to ante-mortem stress; pH below 5.5; poor water-holding capacity; meat is pale and wet. DFD: dark, firm, dry; caused by high ultimate pH (>6.2) from chronic pre-slaughter stress depleting glycogen; meat is dark and sticky.
13. Grade A: no visible defects; excellent conformation and fleshing; uniform light fat cover. Grade B: minor defects permitted (slight bruising, small skin tear); acceptable fleshing; suitable for whole carcass sale. Grade C: significant defects; used for further processing into sausages or minced chicken.
14. Infundibulum (catches yolk; fertilisation occurs here) → magnum (albumen secreted; 3 hours) → isthmus (shell membranes formed; 1 hour) → uterus/shell gland (calcium shell mineralised; 20 hours) → vagina (cuticle applied) → cloaca (egg laid).
15. Any four: calcium deficiency (thin, soft shells); vitamin D3 deficiency (impaired Ca absorption and shell mineralisation); hen age (older hens lay thinner-shelled eggs); Infectious Bronchitis virus (soft, shell-less, or deformed eggs); heat stress (reduces Ca absorption and shell deposition time).

Long-Answer Questions

1. Processing sequence: catching at night to reduce stress → transport in crates → ante-mortem inspection (veterinarian screens live birds; diseased/moribund birds condemned) → stunning (electrical water bath 20-50 mA; or CO2 controlled atmosphere) → bleeding (jugular vein and carotid artery cut; 90-120 sec bleed-out) → scalding (52-56 degrees Celsius, 90-120 sec; loosens feathers) → de-feathering (rotating rubber-finger picker machines) → evisceration (head, feet, viscera removed; vent opened) → chilling (ice water or air chill to below 4 degrees Celsius). Carcass cuts and yields: DP 72-76% of live weight; whole breast 28-35% RTC; boneless skinless breast fillet 20-25% RTC (highest value); whole leg (drumstick + thigh) 25-30%; wing 8-10%; drumstick alone 12-15%; thigh 12-14%; giblets 4-5%. Meat quality: colour (pale pink normal; PSE = pale, soft, exudative from rapid pH drop; DFD = dark, firm, dry from chronic stress); tenderness (good in young broilers); pH (normal 5.7-6.0; PSE pH <5.5; DFD pH >6.2); microbiological safety (Salmonella, Campylobacter control; chilling to <4 degrees Celsius primary control).
2. Pre-harvest quality factors: genetics (breast yield highly heritable); nutrition (vitamin E improves colour/oxidation stability; excess finisher fat increases carcass fat); age and sex (males grow faster; older/heavier birds have higher DP but coarser fibre). Harvest factors: catching (rough handling causes bruising and downgrading; night catching reduces stress); transport (max 4 hours; avoid overcrowding and heat); stunning (inadequate stunning causes PSE, blood splash, poor bleed-out); scalding temperature (over-scalding damages skin). Ante-mortem inspection: veterinarian/inspector examines live birds at plant entry; identifies infectious disease (ND, AI), systemic illness, tumours (Marek's lymphomas), injury, emaciation; notifiable disease = flock rejection; suspects separated for individual examination. Post-mortem inspection: each carcass and viscera examined after evisceration; checks skin (bruising, tumours, discolouration), muscle (colour, texture, haemorrhage), viscera (liver size and colour; spleen; pericarditis; air sac infection); condemned parts sealed in biohazard containers; condemnation record maintained per batch. Grading: Grade A (no defects; excellent conformation and fleshing; uniform fat); Grade B (minor bruising/skin tear; acceptable fleshing); Grade C (significant defects; further processing into sausages, mince, stock).

3. Egg formation (25-26 hours total): ovary releases one follicle ~30 min after previous lay; yolk caught by infundibulum (fertilisation site); magnum (albumen secreted, 3 hours); isthmus (shell membranes, 1 hour); uterus/shell gland (calcium carbonate shell, 20 hours); vagina (cuticle protein coating applied); laid via cloaca. Egg quality characteristics: external (shell strength >34 N; shell weight 10-11% of egg weight; shell colour breed-determined; egg weight 45-75 g); internal (HU: height of thick albumen/egg weight; Grade AA >72; Grade A 60-72; yolk index 0.40-0.42 fresh, declines with age; air cell: <3 mm Grade AA; blood and meat spots = Grade B). Factors affecting quality: genetics (shell strength, colour, egg size); nutrition (Ca deficiency = thin shell; vitamin D3 deficiency impairs mineralisation; vitamin E and Se protect yolk; xanthophylls determine yolk colour; marigold meal deepens colour); hen age (shell thins progressively, eggs enlarge); disease (IB and ND cause soft, shell-less, or malformed eggs); storage (quality declines rapidly at >20 degrees Celsius; chilling to 12-15 degrees dramatically extends shelf life). Egg collection and storage: collect 2-4 times daily; blunt end up in trays; dry clean (preserves cuticle); wet wash only if necessary with water 10 degrees warmer than egg; store 12-15 degrees Celsius, 70-80% RH. Grading: by size (extra large >68 g; large 60-68 g; medium 53-60 g; small 45-53 g) and quality (Grade AA, A, B); candling lamp detects blood spots, cracks, air cell; automated machines (Moba, Sanovo) combine weighing, candling, crack detection. Value-added products: liquid whole egg/albumen/yolk (pasteurised; for bakeries and food manufacturing); spray-dried egg powder (12-24 months shelf life; infant formula); hard-boiled in brine; scotch eggs; egg rolls; pickled eggs.

Answers to Pilot Questions [Series 4]

Part 4.1

6. Correct sequence: (1) catching and transport (birds caught at night; placed in crates; transported to processing plant); (2) ante-mortem inspection (veterinarian inspects live birds; diseased birds condemned); (3) stunning (electrical water bath or CO2 controlled

atmosphere; renders birds unconscious); (4) bleeding (jugular vein and carotid artery cut; 90-120 seconds bleed-out); (5) scalding (52-56 degrees Celsius water immersion; 90-120 seconds; loosens feathers); (6) de-feathering (rotating rubber-finger picker machines remove feathers); (7) evisceration (head, feet, and viscera removed); (8) chilling (ice water or air chill to below 4 degrees Celsius).

7. Dressing percentage (DP) is the weight of the dressed carcass (after removal of feathers, head, feet, and all viscera) expressed as a percentage of the live body weight at the time of slaughter. Normal range for commercial broilers: 72 to 76 per cent of live weight. Factors affecting DP include: breed and genetics (broiler hybrids bred for high DP); slaughter age and weight (DP increases slightly with heavier slaughter weights); gut fill (hence the 6-8 hour pre-slaughter feed withdrawal to reduce gut weight).
8. Whole breast (with bone and skin): 28-35% of RTC weight; the largest and most commercially important carcass cut. Boneless skinless breast fillet: 20-25% of RTC weight; highest value per kg. Whole leg (drumstick + thigh): 25-30% of RTC weight. Wing: 8-10% of RTC weight.
9. PSE (pale, soft, exudative): caused by acute ante-mortem stress (fear, fighting, heat during catching, transport, or lairage) which depletes muscle glycogen through rapid anaerobic metabolism; this causes rapid post-mortem pH drop to below 5.5 (normally pH reaches 5.7-6.0 over several hours); the rapid pH drop at high carcass temperature (before chilling) denatures sarcoplasmic proteins, causing the meat to appear pale and have poor water-holding capacity with excessive drip loss. DFD (dark, firm, dry): caused by chronic pre-slaughter stress (long-term feed restriction, sustained fighting, prolonged transport) which depletes muscle glycogen stores before slaughter; with insufficient glycogen for post-mortem lactic acid production, the muscle pH remains high (>6.2); high pH meat is dark in colour, has a sticky surface, excellent water-holding capacity, and is firmer than normal; it has a shorter shelf life due to high pH favouring bacterial growth.
10. Rapid chilling is critical for two reasons: (1) meat quality: muscles and fat undergo post-mortem changes including rigor mortis and enzymatic activity; chilling below 4 degrees Celsius slows these reactions, reducing drip loss, PSE development risk, and lipid oxidation that causes rancid flavour; rapid chilling also limits the activity of endogenous proteases that would tenderise meat too quickly and produce off-flavours; (2) food safety:

bacterial pathogens (Salmonella, Campylobacter, E. coli, Listeria) multiply rapidly on carcass surfaces at temperatures above 10 degrees Celsius; chilling to below 4 degrees Celsius within 4 hours of slaughter reduces bacterial multiplication to safe levels; Salmonella contamination of broiler carcasses at slaughter is controlled primarily by rapid chilling combined with decontamination treatments.

Part 4.2

11. Four pre-harvest factors: (1) Breed and genetics: breast muscle yield, feathering characteristics, and skin quality are highly heritable; broiler hybrids are specifically selected for high breast yield (20-25% of RTC weight) and good skin quality; poor conformation genetics cause crooked keel bone and other defects that automatically reduce carcass grade. (2) Nutrition: dietary vitamin E supplementation in the final 7 days before slaughter reduces meat discolouration and lipid oxidation; excessive dietary fat in the finisher diet increases carcass fat percentage and may reduce Grade A classification. (3) Age and sex: male broilers grow faster than females but have lower breast yield at the same live weight; older birds have coarser muscle fibre texture; as slaughter weight increases, dressing percentage increases slightly. (4) Disease history: subclinical respiratory disease causes air sacculitis that is detected at post-mortem inspection and leads to condemnation of affected air sacs and surrounding tissue; Marek's disease tumours in viscera and muscle cause widespread condemnation.
12. Rough catching causes bruising in two ways: (1) physical impact — catching workers grabbing birds by the wings rather than the legs, dropping birds, or throwing them into crates causes haemorrhage into breast muscle and skin; bruising is often not visible until after scalding and de-feathering; (2) pile-up pressure — when birds are overcrowded in crates or pile on top of each other in corners during catching, the weight of other birds compresses capillaries causing bruising. Prevention: train catching crews in correct technique (grasp both legs, lower gently into crate); avoid catching in hot daylight hours (darkness calms birds); maintain crate stocking density limits; move crates gently; ensure catchers have adequate light to see what they are doing.

13. Ante-mortem inspection is conducted by a veterinarian or authorised meat inspector at the processing plant before slaughter. The inspector examines each batch of arriving birds while still in their transport crates, and then individually suspects on an inspection platform. Conditions that lead to condemnation: (1) notifiable disease (Newcastle disease, Highly Pathogenic Avian Influenza — entire flock condemned and processing plant temporarily closed for decontamination); (2) signs of systemic infectious disease (severe depression, respiratory distress, cyanotic wattles, neurological signs) — individual birds or the whole flock may be condemned; (3) severe injuries making the bird incapable of normal movement or suffering; (4) severe emaciation indicating chronic disease or prolonged feed deprivation.
14. Post-mortem inspection is performed on each carcass and its viscera on the processing line immediately after evisceration. What is examined: (1) Skin: inspected for bruising (haemorrhage in subcutaneous tissue), tumours (Marek's lymphomas present as pale firm nodules), cellulitis (subcutaneous bacterial infection causing yellow-green discolouration), and abnormal pigmentation; (2) Muscle: colour (dark red = DFD; pale = PSE; green = Clostridium infection), texture, and haemorrhage; (3) Viscera: liver (enlarged or pale yellow = fatty liver; green/swollen = avian cholera; tumours = Marek's); spleen (enlarged = viral or bacterial disease); heart (pericarditis from E. coli); lungs (air sacculitis from chronic respiratory disease); intestines (congestion, haemorrhage, worms). Condemned carcasses and parts are placed in sealed, locked condemnation containers.
15. Grade A: no visible defects; normal conformation (no crooked keel, deformed wings, or twisted legs); excellent fleshing (thick even breast, thigh, and drumstick muscle coverage); uniform light fat layer under intact skin; no bruising, skin tears, or missing parts; suitable for premium whole bird or portioned retail sale. Grade B: minor defects are acceptable; slight bruising (small area, not on breast); one small skin tear (not on breast); slightly reduced fleshing on thighs or drumstick; intact skin; suitable for standard whole carcass or portioned retail sale at reduced price. Grade C: significant defects; extensive bruising; multiple skin tears; clearly reduced fleshing; not suitable for whole carcass retail sale; used exclusively for further processing into minced chicken, sausages, nuggets, or chicken stock where the defects are not visible in the finished product.

Part 4.3

1. Oviduct passage of the egg: (1) Infundibulum (funnel-shaped opening; catches the ovulated yolk within minutes of ovulation; fertilisation by sperm occurs here if sperm are present in the oviduct; the egg remains in the infundibulum for approximately 15 minutes); (2) Magnum (the longest oviduct section; takes approximately 3 hours; thick and thin albumen proteins are secreted layer by layer around the yolk; albumen constitutes approximately 58% of total egg weight); (3) Isthmus (approximately 1 hour; the two shell membranes — inner and outer — are formed around the albumen; water is also absorbed into the albumen here, increasing its volume); (4) Uterus/shell gland (the longest dwell time, approximately 20 hours; calcium carbonate crystals are deposited on the outer shell membrane by active transport from blood; the cuticle protein coating is applied last); (5) Vagina and cloaca (egg passes through the vagina and is expelled through the cloaca).
2. The Haugh Unit (HU) is a numerical index of albumen quality named after Raymond Haugh who developed it in 1937. It is calculated from the height of the thick (inner) albumen layer measured against a specific point on the albumen surface, corrected for egg weight, using the formula: HU = 100 x log(H - 1.7W^0.37 + 7.57), where H is albumen height in mm and W is egg weight in grams. What it measures: the structural integrity of the ovomucin protein network in the thick albumen; fresh eggs have a tall, firm, compact albumen dome (high HU); as eggs age or are exposed to heat, the ovomucin protein network breaks down (through enzymatic activity and pH changes), the albumen spreads flat and watery (low HU); this decline in albumen structure reduces the culinary quality of the egg (it cannot hold its shape when fried or poached).
3. Four factors affecting eggshell quality: (1) Dietary calcium (layer diet must supply 3.5-4.0% calcium; deficiency causes thin, porous, or soft-shelled eggs; calcium is deposited at a rate of 2.0-2.5 g per shell over 20 hours; blood calcium must remain adequate throughout the shell-forming period, which requires both dietary supply and efficient intestinal absorption); (2) Vitamin D3 (required for calcium absorption from the intestine and for the active transport of calcium ions through the uterine epithelium into the

forming shell; vitamin D3 deficiency causes thin, rough, or misshapen shells even when dietary calcium is adequate); (3) Hen age (shell quality declines progressively as laying hens age beyond 40 weeks; the total calcium-depositing capacity of the shell gland remains relatively fixed while egg size increases with age, spreading the same calcium over a larger surface area and producing proportionally thinner shells); (4) Disease (Infectious Bronchitis virus infects the reproductive tract epithelium, damaging the shell gland mucosa directly; affected hens lay soft-shelled, wrinkled, thin-shelled, or shell-less eggs).

4. Internal egg quality declines with increasing storage temperature through two main mechanisms: (1) CO2 loss: the fresh egg contains dissolved CO2 in the albumen; CO2 is alkaline when dissolved (carbonic acid equilibrium); as CO2 diffuses out through the shell pores after laying, the albumen pH rises from 7.6 (fresh) to 9.0 to 9.5; this alkaline pH weakens the ovomucin protein network that maintains albumen gel structure; the rate of CO2 loss doubles approximately every 10 degrees Celsius increase in temperature; at Nigerian ambient temperatures (30-35 degrees Celsius) the egg albumen becomes watery within 5-7 days; at 12-15 degrees Celsius the same deterioration takes 30-40 days. (2) Moisture loss: water evaporates through the approximately 7,000 pores in the shell; evaporation rate is proportional to temperature and inversely proportional to ambient relative humidity; moisture loss enlarges the air cell and concentrates the remaining albumen, reducing yolk index and overall quality.
5. Yolk colour is determined entirely by the concentration and type of xanthophyll carotenoid pigments present in the diet of the hen; the hen cannot synthesise carotenoids herself and must absorb them from dietary sources. The main dietary carotenoid sources: maize grain (yellow corn contains zeaxanthin and lutein; white maize provides no xanthophyll and produces pale yellow yolks); marigold flower meal (dried Tagetes erecta petals; very high in lutein and zeaxanthin; most concentrated xanthophyll source commercially available); paprika (Capsicum annuum extract; high in capsanthin and capsorubin; produces deep orange-red yolk colour); palm oil (contains beta-carotene which is only weakly pigmenting). Producers deepen yolk colour by: including yellow maize rather than white maize as the primary energy ingredient; supplementing with marigold meal at 2-8 kg per tonne of feed; adding synthetic carotenoids (canthaxanthin,

beta-apo-8-carotenal) at permitted levels; the Roche yolk colour fan (a standardised fan with 15 colour shades from pale yellow to deep orange) is used to match desired yolk colour to the target market preference.

Part 4.4

1. Frequent egg collection is important in Nigerian conditions for three reasons: (1) Quality preservation: in Nigeria's ambient temperature of 28-35 degrees Celsius, eggs lose quality very rapidly; every hour at 30 degrees Celsius is equivalent to approximately 4 days of storage at 4 degrees Celsius in terms of HU decline; collecting 2-4 times per day reduces the average time each egg spends at ambient temperature before cooling, directly improving delivered quality to the consumer; (2) Reduction of floor eggs: hens that do not reach the nest box in time lay their eggs on the litter floor; floor eggs are heavily contaminated with faeces, litter bacteria, and debris; frequent collection and prompt correction of any factors causing floor eggs (blocked nest box access, inadequate nest numbers, sudden light changes) reduces the proportion of contaminated eggs; (3) Reduction of cracked and broken eggs: eggs accumulate in nests; in battery cage systems, eggs roll slowly to the collection trough; the longer eggs remain in the nest or trough, the more likely they are to be cracked by subsequent eggs or by hens standing on them; frequent collection reduces this collision risk.
2. Dry cleaning (using a clean cloth, fine sandpaper, or a specialised abrasive egg cleaning brush to remove dirt from the shell surface without moisture) is preferred for three reasons: (1) Cuticle preservation: the eggshell cuticle is a thin protein coating (0.5-12 micrometres thick) applied to the outer shell surface in the hen's vagina just before laying; it physically blocks the 7,000 pores in the shell from bacterial entry and reduces the rate of CO2 and moisture loss; the cuticle is water-soluble and is dissolved by wet washing, permanently removing this protective barrier; (2) Reduced bacterial suction: the egg interior is slightly negative in pressure relative to the outside; if the shell is wetted with water that is the same temperature as or cooler than the egg, the contraction of the egg contents creates a suction that draws bacteria on the wet shell surface through the

pores into the albumen; (3) Shell damage: commercial egg washers operating with chlorinated water at incorrect pH or temperature can microscopically etch the shell surface, increasing porosity and subsequent contamination risk.

3. Standard commercial egg size grades by weight: Extra large: >68 g per egg; Large: 60 to 68 g; Medium: 53 to 60 g; Small: 45 to 53 g; Peewee: <45 g. In Nigerian commercial practice, grading is most commonly done by the categories Large (>60 g), Medium (53-60 g), and Small (<53 g); extra large and peewee categories are less formally applied. Egg size is determined primarily by hen age (young hens lay small eggs; egg size increases throughout the laying cycle), breed genetics (production-line Isa Brown or Lohmann Brown lay larger eggs than White Leghorn at the same age), and nutrition (dietary linoleic acid content influences yolk size and total egg weight).
4. Automated egg grading machines work by passing eggs through several sequential inspection and measurement stations on a continuous conveyor system: (1) Weighing station: each egg passes over individual load cells or is lifted onto a precision balance; the weight is recorded electronically and the egg is assigned to a size grade; (2) Candling station: each egg passes over a high-intensity light source from below; a camera or photodetector above captures the silhouette; software detects blood spots (dark shadows in the albumen), meat spots, cracks (hairline cracks transmit light differently from intact shell), air cell size (air cell appears as a dark area at the blunt end), and internal abnormalities; (3) Shell defect detection: some machines include an additional acoustic crack detection system (a small hammer taps the egg; the acoustic response distinguishes cracked from intact shells with high accuracy); (4) Packing station: eggs are sorted by grade and size into cartons (6, 12, or 30 eggs) or trays; a date stamp, farm code, and grade mark may be applied automatically.
5. Four egg products with market applications: (1) Pasteurised liquid whole egg (the shell is broken, yolk and white mixed, then heat-pasteurised at 60-65 degrees Celsius for 2-3 minutes to destroy Salmonella; packaged in sealed cartons; market application: industrial bakeries, pastry manufacturers, hotels, and catering operations that use large quantities of eggs daily but cannot economically break and handle shells at scale); (2) Spray-dried whole egg powder (liquid egg is atomised into a hot-air chamber and instantly dried to 2-5% moisture content; market application: infant formula manufacturers, pharmaceutical

excipient producers, confectionery manufacturers who need a shelf-stable egg product with 12-24 month shelf life); (3) Hard-boiled eggs in brine (eggs hard-boiled, shelled, and stored in salted brine solution in sealed jars or bags; market application: Nigerian roadside food vendors, fast food chains, school canteens; convenient protein snack requiring no cooking at the point of sale); (4) Scotch eggs (hard-boiled eggs fully encased in seasoned minced meat, coated in breadcrumbs, and deep-fried; market application: Nigerian street food stalls, supermarket snack sections, and roadside kiosks; one of the most popular convenience protein foods in Lagos and other southern cities).

References and Attributions [Series 4]

Textual References (Books and External Sources)

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3. Stadelman, W. J., & Cotterill, O. J. (Eds.). (1995). Egg science and technology (4th ed.). Food Products Press.
4. FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.

Figures, Plates, Tables, and Boxes

1. Figure 4.1: Standard broiler carcass cuts diagram Attribution: AI generated. Suggested OER search string: "broiler carcass cuts diagram breast thigh drumstick wing yield percentage OER".
2. Figure 4.2: Post-mortem poultry carcass inspection photograph Attribution: AI generated. Suggested OER search string: "post mortem poultry carcass inspection processing plant evisceration OER photograph".

3. Box 4.1: Egg quality grading criteria by grade AA, A, and B Attribution: AI generated. Suggested OER search string: "egg quality grading criteria internal external Haugh unit air cell shell OER box".
4. Figure 4.3: Commercial egg grading and packing line photograph Attribution: AI generated. Suggested OER search string: "commercial egg grading machine packing line automated photograph OER".
5. Box 4.2: Egg value-added products and Nigerian market applications Attribution: AI generated. Suggested OER search string: "egg value added products liquid dried powder hard boiled scotch egg Nigeria market OER box".

Course code: AGE 406

Course title: Poultry Production Education

Series 5: Marketing, Welfare, and Legislation in Poultry Production

- **Part 5.1: Poultry Marketing in Nigeria**
  - Sub Part 5.1.1: Structure of the Nigerian poultry market
  - Sub Part 5.1.2: Marketing channels and price determination
  - Sub Part 5.1.3: Market information and price risk management
- **Part 5.2: Poultry Health and Disease Control**
  - Sub Part 5.2.1: Major poultry diseases in Nigeria
  - Sub Part 5.2.2: Biosecurity and disease prevention
  - Sub Part 5.2.3: Vaccination programmes and drug use
- **Part 5.3: Poultry Welfare**
  - Sub Part 5.3.1: Principles of animal welfare
  - Sub Part 5.3.2: Welfare indicators and assessment
  - Sub Part 5.3.3: Welfare issues in commercial poultry systems
- **Part 5.4: Legislation, Food Safety, and the Future of Nigerian Poultry**
  - Sub Part 5.4.1: Nigerian legislation governing poultry production
  - Sub Part 5.4.2: Food safety and HACCP in poultry production
  - Sub Part 5.4.3: Challenges and opportunities in Nigerian poultry

Introduction

A well-managed flock that produces quality meat and eggs will fail commercially if the producer cannot market the product effectively, control disease, comply with food safety regulations, and meet welfare standards. This final Series integrates the production knowledge of Series 1 to 4 with the marketing, disease control, welfare, and legislative frameworks that govern commercial poultry production in Nigeria.

Topics covered include the structure of Nigerian poultry markets and price formation, major diseases and their control, the Five Freedoms framework for animal welfare, welfare assessment, Nigerian legislation governing poultry production, food safety and HACCP principles, and the challenges and opportunities facing the Nigerian poultry industry.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** describe the structure of the Nigerian poultry market and the major marketing channels (Linked to Part 5.1),
- **SLO 5.2** explain price determination and risk management strategies for Nigerian poultry producers (Linked to Part 5.1),
- **SLO 5.3** describe the major poultry diseases in Nigeria, their signs, and control measures (Linked to Part 5.2),
- **SLO 5.4** describe biosecurity principles and explain the design of a vaccination programme (Linked to Part 5.2),
- **SLO 5.5** explain the Five Freedoms framework and describe welfare indicators used to assess commercial poultry flocks (Linked to Part 5.3),
- **SLO 5.6** describe the major welfare issues in commercial poultry systems and explain how they are addressed (Linked to Part 5.3),
- **SLO 5.7** describe the Nigerian legislative framework governing poultry production and explain HACCP principles (Linked to Part 5.4), and

- **SLO 5.8** identify the major challenges and opportunities facing Nigerian poultry production and propose solutions (Linked to Part 5.4).

5.1 Poultry Marketing in Nigeria

5.1.1 Structure of the Nigerian poultry market

The Nigerian poultry market operates through three main segments: live bird markets (LBMs), where most urban Nigerians purchase whole live chickens for home slaughter; fresh/chilled chicken retail, supplied by commercial processors and supermarkets (still a small but growing segment); and the informal cooked chicken market (suya, pepper soup, and fried chicken roadside stalls). Eggs are sold predominantly through open-tray retail in markets, kiosks, and roadside stalls; supermarket egg sales account for less than 10% of total volume.

The live bird market remains dominant because most Nigerian consumers prefer freshly slaughtered chicken whose provenance they can observe; cold chain infrastructure is insufficient for widespread chilled or frozen poultry retail outside major cities. Seasonal price patterns are strong: demand and prices peak during festive seasons (Christmas, Eid, Easter) and school resumption periods; prices fall during school holidays when institutional catering demand drops. Price volatility is one of the most significant business risks for Nigerian poultry producers.

Fill in the blank: The _____ bird market remains the dominant poultry marketing channel in Nigeria because consumers prefer freshly slaughtered chicken and cold chain infrastructure is insufficient for widespread chilled retail.

5.1.2 Marketing channels and price determination

Marketing channels: integrated producers sell directly to supermarkets, fast food chains, and institutional buyers (schools, hospitals, military, hotels) at negotiated contract prices; semi-commercial farmers sell to wholesalers who supply live bird markets; smallholder farmers sell to village traders or directly at farm gate. Direct farm-to-consumer marketing through WhatsApp

groups, social media, and online platforms is growing, particularly for premium or free-range products.

Poultry price determination factors: feed cost (65 to 70% of production cost; rising maize and soyabean prices push up production cost and ultimately market price); production volume (supply-demand balance; when many farmers sell simultaneously, prices fall); seasonal demand cycles; import competition (illegal importation of frozen chicken at below-cost prices depresses domestic market prices); and transport and handling costs between the farm and the market.

Fill in the blank: Feed cost constitutes 65 to _____ per cent of broiler production cost; increases in maize and soyabean prices directly raise production cost and ultimately push up chicken retail prices.

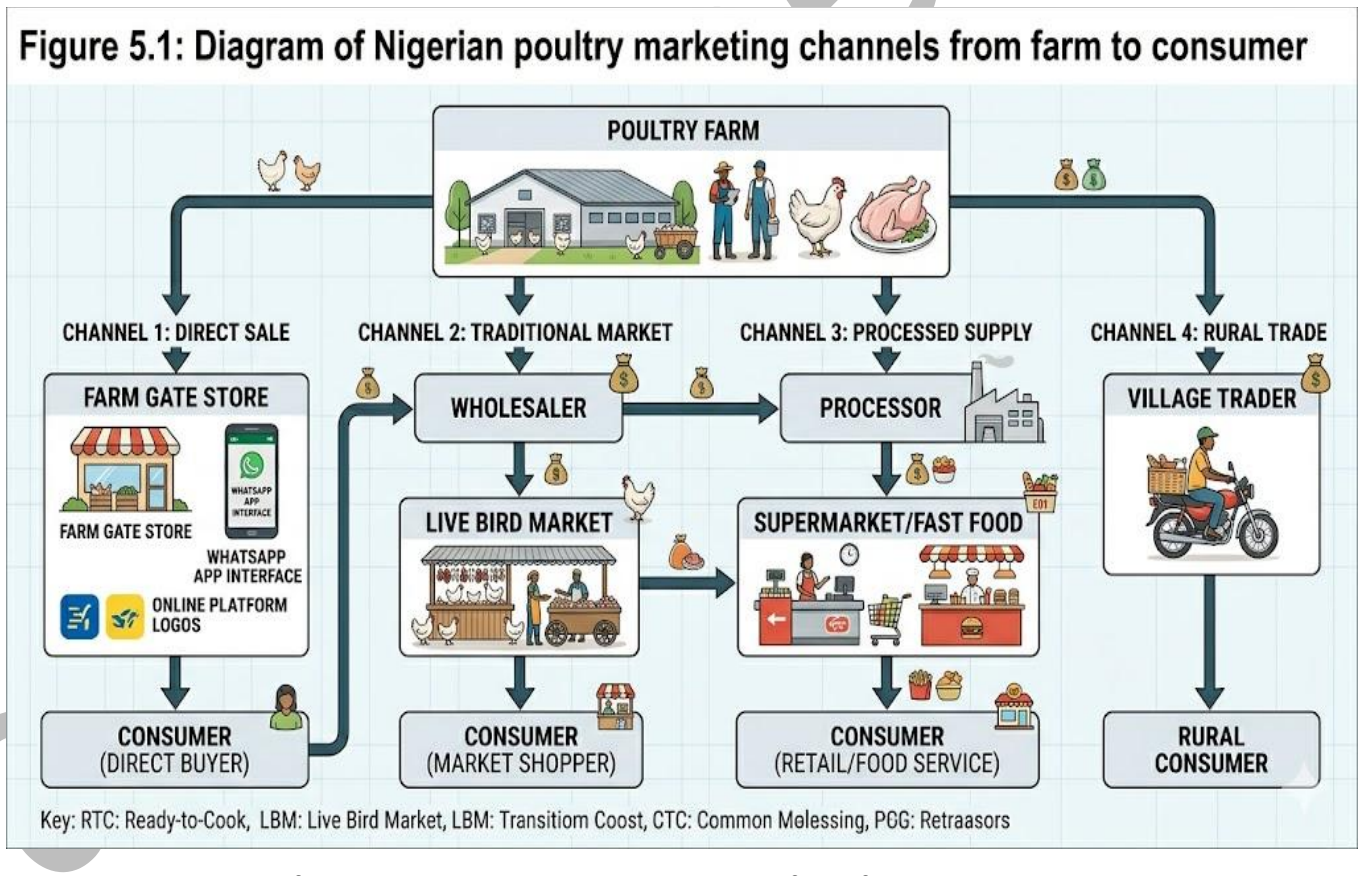

Figure 5.1: Diagram of Nigerian poultry marketing channels from farm to consumer

5.1.3 Market information and price risk management

Price risk management strategies for Nigerian poultry producers: forward contracts (agreeing price with a buyer before production; reduces price uncertainty but requires consistent supply of agreed quality); diversification of marketing channels (selling to multiple buyers reduces dependence on any single market); production scheduling (timing flock placement to harvest birds during high-demand festive periods when prices are highest); and cost control (reducing feed cost through bulk purchase, alternative ingredients, or on-farm feed milling reduces breakeven price).

Market information tools: Poultry Association of Nigeria (PAN) publishes weekly price data; commodity market price bulletins from the Federal Ministry of Agriculture; online platforms (AgriTech Nigeria, Farmcrowdy, ThriveAgric) provide real-time market price data; WhatsApp and SMS networks among traders provide informal but timely price signals. Information asymmetry (buyers know more than sellers) disadvantages smallholder producers; access to market information reduces this asymmetry and improves bargaining power.

Fill in the blank: Forward _____ (agreeing price with a buyer before production begins) reduces price uncertainty for the producer but requires consistent supply of agreed quantity and quality throughout the contract period.

Pilot questions 5.1

- Describe the three main segments of the Nigerian poultry market.
- Explain why the live bird market dominates Nigerian poultry retail.
- State five factors that determine poultry prices in Nigeria.
- Describe three price risk management strategies for Nigerian poultry producers.
- Explain how market information tools reduce the disadvantage of smallholder producers.

5.2 Poultry Health and Disease Control

5.2.1 Major poultry diseases in Nigeria

Newcastle Disease (ND): the most economically important poultry disease in Nigeria; caused by avian paramyxovirus-1 (APMV-1); spreads rapidly by respiratory droplets and contaminated equipment; signs include nervous signs (torticollis, paralysis), respiratory distress, green diarrhoea, and sudden death; mortality can reach 100% in unvaccinated flocks. Control: vaccination is the only effective prevention; slaughter of infected flocks in high-income country control programmes; no treatment for viral disease.

Infectious Bursal Disease (Gumboro/IBD): highly contagious viral disease of the bursa of Fabricius in 3 to 6 week old chicks; causes immunosuppression, making birds susceptible to secondary infections; signs: depression, ruffled feathers, watery diarrhoea, trembling; mortality 5 to 30%; maternal antibody interference complicates vaccination timing. Avian Influenza (AI): highly contagious; Highly Pathogenic AI (HPAI H5N1) causes near-100% mortality and is a major zoonotic risk; notifiable disease with mandatory reporting and depopulation. Marek's Disease (MD): herpesvirus causing lymphoma and nerve paralysis in young chickens; controlled by vaccination at hatch.

Fill in the blank: Newcastle Disease is caused by avian paramyxovirus-1 (APMV-1); it causes nervous signs, respiratory distress, and sudden death with mortality up to _____ per cent in unvaccinated flocks.

Disease	Causative Agent	Key Clinical Signs	Control Measures
Newcastle Disease (ND)	Avian Paramyxovirus-1 (APMV-1)	Nervous signs, green diarrhoea, sudden death	Vaccination (live and killed vaccines)
Infectious Bursal Disease (IBD/Gumboro)	Birnavirus	Depression, trembling, immunosuppression in 3–6 week chicks	Vaccination

Avian Influenza (AI H5N1)	Influenza A virus (HPAI)	Near-100% mortality; respiratory distress	Strict biosecurity, depopulation (notifiable disease)
Marek's Disease	Herpesvirus	Nerve paralysis, lymphomas	In-ovo or at-hatch vaccination
Coccidiosis	*Eimeria* spp.	Bloody diarrhoea in 2–6 week chicks	Coccidiostats in feed or live oocyst vaccine
Infectious Bronchitis (IB)	Coronavirus	Respiratory signs, poor egg quality	Vaccination

Box 5.1: Major poultry diseases in Nigeria: causative agent, key signs, and control

5.2.2 Biosecurity and disease prevention

Biosecurity is the primary disease prevention tool; no vaccination programme compensates for poor biosecurity. External biosecurity: perimeter fencing; controlled entry points; vehicle disinfection at the farm gate; visitor logbook; quarantine of all incoming birds (minimum 3 weeks); source birds only from NAFDAC-registered hatcheries. Internal biosecurity: one person per house; house-specific footwear and clothing; foot baths at all house entrances; AIAO management; proper litter management; rodent and wild bird control.

Dead bird disposal is a critical biosecurity issue: dead birds must be incinerated, buried in a deep pit (minimum 2 m), or rendered; leaving dead birds in or near the house allows scavengers and flies to spread pathogens to adjacent houses or farms. Water source hygiene: nipple drinker systems fed from a chlorinated header tank (1 to 2 ppm free chlorine) prevent waterborne Salmonella, E. coli, and Mycoplasma transmission; open drinkers are a major disease amplification point.

Fill in the blank: Dead birds must be incinerated or buried at minimum _____ m depth; leaving carcasses exposed allows scavengers and flies to spread pathogens between houses or farms.

5.2.3 Vaccination programmes and drug use

Vaccination programme design principles: use vaccines appropriate to the field challenge (live vaccines provide mucosal immunity; killed vaccines boost systemic antibody titre); match vaccine strain to circulating field virus (a mismatch reduces protection); time vaccination to coincide with the end of maternal antibody decay (too early = maternal antibody interference; too late = susceptibility gap); ensure vaccine viability by maintaining the cold chain at all stages of handling and administration.

Responsible antibiotic use: antibiotics should only be used under veterinary prescription for treatment of confirmed bacterial infections; prophylactic use of critically important antibiotics (fluoroquinolones, third-generation cephalosporins) is prohibited under the Nigerian National Action Plan for Antimicrobial Resistance. Growth promoter antibiotics are being phased out globally; their use in food-producing animals creates antimicrobial resistance (AMR) risks for human health. Coccidiostats are feed additives licensed for preventive use in broiler production.

Fill in the blank: Prophylactic use of critically important antibiotics such as _____ is prohibited under Nigeria's National Action Plan for Antimicrobial Resistance; antibiotics should only be used under veterinary prescription for confirmed bacterial infections.

Pilot questions 5.2

- Describe Newcastle Disease: causative agent, transmission, signs, and control.
- Explain why Gumboro disease is so damaging to young chicks.
- State five external biosecurity measures for a commercial poultry farm.
- Explain the principles that should guide the design of a poultry vaccination programme.
- Explain what antimicrobial resistance is and why prophylactic antibiotic use in poultry is a public health concern.

5.3 Poultry Welfare

5.3.1 Principles of animal welfare

The Five Freedoms framework (Farm Animal Welfare Council, UK, 1979) provides the international standard for assessing and ensuring animal welfare: (1) Freedom from hunger and thirst (access to fresh water and a diet to maintain full health and vigour); (2) Freedom from discomfort (an appropriate environment with shelter and a comfortable resting area); (3) Freedom from pain, injury, or disease (prevention or rapid diagnosis and treatment); (4) Freedom to express normal behaviour (sufficient space, proper facilities, and appropriate company of the animal's own kind); (5) Freedom from fear and distress (conditions and treatment that avoid mental suffering).

The Five Freedoms have evolved into a more positive welfare sciences framework — the Five Domains model — which also considers positive mental states and the overall quality of life. Welfare is a spectrum, not a binary; a flock can have good welfare in some dimensions (nutrition, health) but poor welfare in others (behaviour, comfort). The goal of progressive poultry management is to achieve good welfare across all five dimensions simultaneously.

Fill in the blank: The Five _____ framework provides the international standard for animal welfare assessment; it was developed by the Farm Animal Welfare Council in 1979 and covers hunger, discomfort, pain/disease, normal behaviour, and fear.

5.3.2 Welfare indicators and assessment

Welfare indicators assess the actual welfare state of the birds rather than inputs alone. Broiler welfare indicators: foot pad dermatitis score (FPD; scored 0 to 4; high FPD indicates wet litter and management failure); hock burn score (similar to FPD; indicates prolonged contact with wet litter); gait score (0 to 5 scale; scores above 2 indicate leg problems affecting walking ability and welfare); breast blisters (skin lesions from prolonged floor contact; indicate litter quality problems or insufficient exercise).

Layer welfare indicators: feather cover score (loss of feathers indicates feather-pecking or moult; poor feather cover increases cold stress); bone strength (osteoporosis is common in laying hens due to high calcium mobilisation for shell formation; fracture rate is a welfare and food safety indicator); mortality and culling rate; behaviour observation (time spent feeding, drinking, preening, resting, and performing dustbathing). The Welfare Quality Protocol provides a standardised flock-level welfare assessment system used globally.

Fill in the blank: Foot pad _____ (FPD) is a key broiler welfare indicator scored 0 to 4; high scores indicate wet litter and poor management, and are associated with lameness, pain, and reduced growth performance.

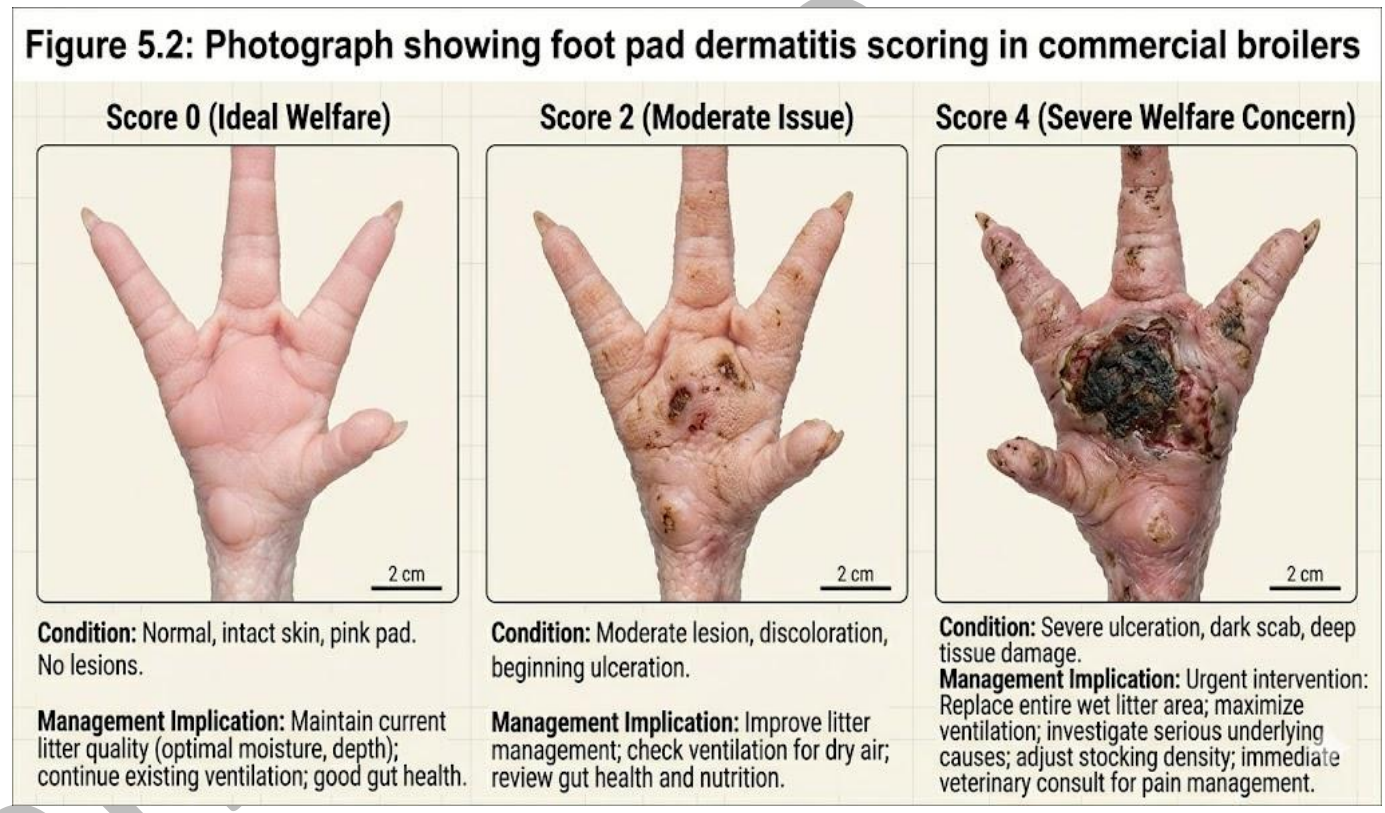

Figure 5.2: Photograph showing foot pad dermatitis scoring in commercial broilers

5.3.3 Welfare issues in commercial poultry systems

Battery cage welfare issues: laying hens in battery cages cannot perform natural behaviours including wing-stretching, dustbathing, nesting, and perching; the wire floor causes foot and leg problems; the close confinement causes chronic frustration and stereotypic behaviours. The

European Union banned conventional battery cages in 2012; Nigeria has no equivalent legislation yet, though animal welfare NGOs are advocating for reform. Enriched cages (providing a nest box, perch, and scratch area) partially address these concerns.

Broiler welfare issues: fast-growing commercial broiler hybrids have leg health problems (lameness, skeletal deformities) caused by the imbalance between rapid muscle mass growth and skeletal development; ascites (water belly) is a metabolic disorder of fast-growing broilers in poor ventilation; heat stress is the major welfare challenge in Nigerian conditions; high stocking density restricts normal movement and social behaviour. Genetic selection for moderate growth rate and good leg health, combined with appropriate stocking density management, are the primary solutions.

Fill in the blank: _____ (water belly) is a metabolic welfare disorder of fast-growing commercial broilers caused by pulmonary hypertension and right-heart failure; it is exacerbated by poor ventilation and high altitude.

Pilot questions 5.3

1. State and briefly explain each of the Five Freedoms of animal welfare.
2. Describe foot pad dermatitis as a welfare indicator and explain what high FPD scores indicate.
3. State three welfare problems associated with battery cage housing of layers.
4. Explain two welfare problems specific to fast-growing commercial broiler hybrids.
5. Explain why heat stress is a major poultry welfare challenge in Nigeria and describe two mitigation strategies.

5.4 Legislation, Food Safety, and the Future of Nigerian Poultry

5.4.1 Nigerian legislation governing poultry production

Federal legislation relevant to Nigerian poultry production: Animal Diseases (Control) Act (CAP A17 LFN 2004): empowers the Federal Ministry of Agriculture to control notifiable animal

diseases including Newcastle disease, Avian Influenza, and Marek's disease; authorises compulsory slaughter of infected flocks and movement restrictions. NAFDAC Act: requires that all commercial food products including processed poultry meat and eggs carry NAFDAC registration numbers; governs food safety standards and residue limits for veterinary drugs.

Standards Organisation of Nigeria (SON): sets quality standards for poultry products; Nigerian Industrial Standard (NIS) for poultry meat and eggs. Veterinary Surgeons Act: controls the practice of veterinary medicine; prescription of veterinary drugs requires a licensed veterinarian. National Livestock Transformation Plan (NLTP): federal policy framework targeting increased domestic poultry production to reduce import dependence. State government regulations on live bird markets, slaughter facilities, and environmental permits for large farms complement the federal regulatory framework.

Fill in the blank: The Animal Diseases (Control) Act (CAP _____ LFN 2004) empowers the Federal Ministry of Agriculture to control notifiable diseases and authorise compulsory slaughter of infected poultry flocks.

5.4.2 Food safety and HACCP in poultry production

Food safety in poultry production focuses on preventing biological hazards (Salmonella, Campylobacter, Listeria, avian influenza), chemical hazards (antibiotic and pesticide residues, heavy metals), and physical hazards (bone splinters, metal fragments, plastic contamination) from reaching the consumer. Hazard Analysis and Critical Control Points (HACCP) is the systematic preventive approach to food safety: identify hazards, determine Critical Control Points (CCPs), establish control limits, monitor CCPs, take corrective action when limits are exceeded, keep records, and verify the system.

Critical Control Points in poultry processing: chilling (carcass temperature must reach below 4 degrees Celsius within 4 hours of slaughter; CCP for microbial growth prevention); drug withdrawal (7-day withdrawal period before slaughter; CCP for residue control); ante-mortem and post-mortem inspection (CCP for disease hazard control); scalding temperature control (CCP for de-feathering efficiency and microbial reduction). HACCP is mandatory for NAFDAC-registered poultry processing plants in Nigeria and is required for export certification.

Fill in the blank: HACCP (Hazard Analysis and Critical _____ Points) is a systematic food safety management system; chilling, drug withdrawal, and inspection are critical control points in poultry processing.

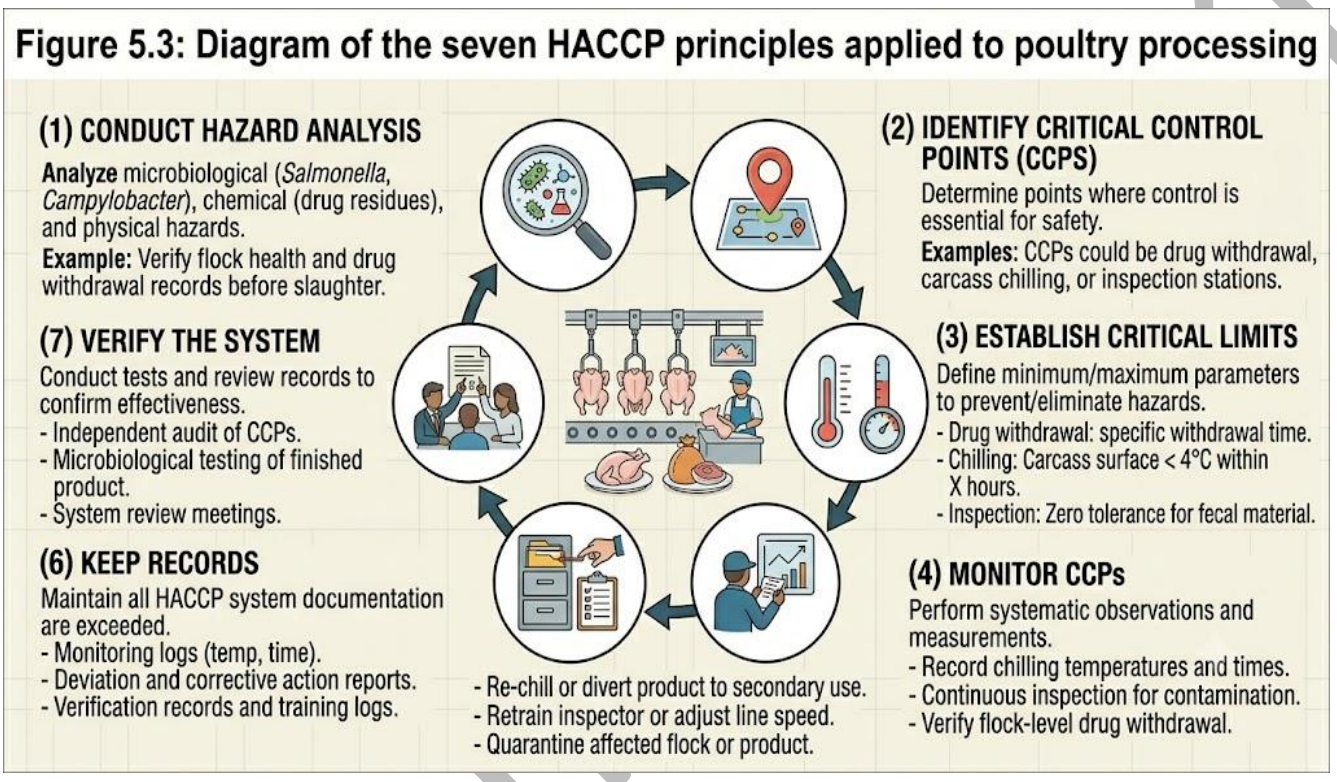

Figure 5.3: Diagram of the seven HACCP principles applied to poultry processing

5.4.3 Challenges and opportunities in Nigerian poultry

Major challenges: feed cost (65 to 70% of production cost; volatile maize and soyabean prices driven by import dependency, forex fluctuation, and climate variability); disease burden (Newcastle disease, Gumboro, and HPAI remain poorly controlled in backyard flocks that serve as reservoir hosts); inadequate cold chain infrastructure (limits market radius and forces live bird marketing which increases biosecurity risk); lack of formal credit at affordable rates; and competition from cheap imported frozen poultry products.

Significant opportunities: large and growing domestic protein demand (Nigeria's 220 million population; rising urbanisation and per capita income growth); government import restrictions on poultry products (protecting domestic production); growing formal retail and food service sector

(supermarkets, fast food chains seeking reliable domestic supply); alternative feed ingredients (black soldier fly larvae, duckweed, fermented agro-industrial by-products) offer cost reduction potential; agri-tech solutions (automated farm monitoring, digital disease diagnostics, e-commerce for poultry products) are expanding.

Fill in the blank: Nigeria's growing urban population and rising per capita income create expanding _____ for domestically produced poultry meat and eggs; government import restrictions further protect domestic producers from cheap foreign competition.

Challenges	Details
Feed Cost	Accounts for 65–70% of production cost; volatile maize and soybean prices
Newcastle Disease Reservoirs	Persistent outbreaks in village flocks serving as reservoirs
Inadequate Cold Chain	Forces reliance on live bird marketing
Poor Credit Access	Limited affordable financing options for farmers
Illegal Imports	Smuggled frozen chicken depresses local prices

Opportunities	Details
Growing Protein Demand	Expanding domestic market with 220 million population
Import Restrictions	Government ban/restriction supports local producers
Formal Retail Growth	Rising demand from supermarkets and fast food chains
Alternative Feed Ingredients	Options like black soldier fly larvae and duckweed reduce costs
Digital Platforms	Reduce market information asymmetry and improve farmer-buyer linkages
NLTP Framework	Provides structured pathway for industry development

Box 5.2: Summary of key challenges and strategic opportunities for the Nigerian poultry industry

Pilot questions 5.4

1. State three pieces of Nigerian legislation relevant to poultry production and explain the main provision of each.
2. Explain what HACCP is and state the seven steps of the HACCP system.
3. Identify three Critical Control Points in broiler processing and state the control limit for each.
4. State four major challenges facing the Nigerian poultry industry.
5. State four major opportunities available to the Nigerian poultry industry and suggest how each can be exploited.

Series Summary

This final Series covered marketing, health, welfare, and legislation. Nigerian poultry markets operate through live bird markets (dominant), processors and supermarkets (growing), and informal cooked chicken stalls. Price is determined by feed cost, supply-demand balance, seasonal demand cycles, and import competition; risk is managed through forward contracts, channel diversification, and production scheduling. Major diseases (ND, IBD, AI, Marek's, coccidiosis, IB) are controlled by biosecurity and vaccination; antimicrobial resistance management prohibits prophylactic use of critically important antibiotics.

The Five Freedoms framework (hunger, discomfort, pain/disease, normal behaviour, fear) underpins welfare assessment; broiler welfare indicators include FPD score, hock burn, and gait score; layer welfare indicators include feather cover and bone strength. Battery cages restrict natural behaviour; fast-growing broilers suffer leg health and ascites problems; heat stress is the dominant Nigerian welfare challenge. Relevant legislation includes the Animal Diseases (Control) Act, NAFDAC Act, SON standards, and the NLTP. HACCP is mandatory for registered processors; CCPs include chilling, drug withdrawal, and inspection. Challenges (feed cost, disease, cold chain, credit, imports) and opportunities (domestic demand, import restrictions, formal retail growth, alternative feeds, agri-tech) complete the course. By

completing this Series, you should achieve all eight SLOs (5.1 to 5.8) and all course learning outcomes.

Glossary of Terms

1. **AMR (Antimicrobial Resistance):** the ability of bacteria to resist the effects of antibiotics; promoted by overuse or misuse of antibiotics in livestock and human medicine.
2. **Ascites (water belly):** a metabolic disorder of fast-growing broilers characterised by fluid accumulation in the abdomen; caused by pulmonary hypertension and right-heart failure.
3. **APMV-1:** avian paramyxovirus-1; the causative agent of Newcastle disease; the most economically important poultry virus in Nigeria.
4. **Avian Influenza (AI):** a highly contagious viral disease of poultry caused by influenza A virus; HPAI H5N1 causes near-100% mortality and is a notifiable zoonotic disease.
5. **Biosecurity:** the set of practices designed to prevent the entry of pathogens into a farm and their spread within or from the farm.
6. **Campylobacter:** a bacterial foodborne pathogen commonly carried by poultry; a major cause of human gastroenteritis; controlled by hygiene and rapid chilling.
7. **Coccidiosis:** an intestinal parasitic disease caused by Eimeria protozoa; causes bloody diarrhoea and mortality in young chicks; controlled by coccidiostats or live vaccine.
8. **Critical Control Point (CCP):** a step in the food production process where a control measure can be applied to prevent or eliminate a food safety hazard; examples in poultry processing: chilling, drug withdrawal, inspection.
9. **EPEF:** European Production Efficiency Factor; a composite broiler performance index described in Series 1.

10. **Feather-pecking:** a behavioural problem in poultry where birds peck the feathers of other birds; leads to feather loss, skin injury, and cannibalism; exacerbated by overcrowding and boredom.
11. **Five Freedoms:** the internationally recognised animal welfare framework: freedom from hunger, discomfort, pain/disease, restriction of normal behaviour, and fear/distress.
12. **Foot pad dermatitis (FPD):** inflammation and ulceration of the plantar surface of the broiler foot caused by prolonged contact with wet, ammonia-rich litter; a key welfare indicator.
13. **Forward contract:** a marketing agreement between buyer and seller that fixes price, quantity, quality, and delivery terms before production begins; reduces price risk for the producer.
14. **Gait score:** a 0-5 scoring system assessing broiler walking ability; scores >2 indicate leg health problems affecting welfare.
15. **HACCP:** Hazard Analysis and Critical Control Points; a systematic seven-step preventive food safety management system required for NAFDAC-registered poultry processors.
16. **HPAI:** Highly Pathogenic Avian Influenza; a notifiable disease causing near-100% mortality in poultry; H5N1 is a major zoonotic risk to humans.
17. **IBD (Gumboro disease):** Infectious Bursal Disease; a viral disease of the bursa of Fabricius in young chickens causing immunosuppression; controlled by vaccination.
18. **Infectious Bronchitis (IB):** a coronavirus disease of chickens causing respiratory signs and egg quality problems; controlled by vaccination.
19. **Live bird market (LBM):** a market where poultry are sold alive; the dominant poultry retail channel in Nigeria; a major biosecurity risk for disease spread including HPAI.
20. **Marek's Disease:** a herpesvirus disease of chickens causing peripheral nerve paralysis and lymphoma; controlled by vaccination at hatch.

21. **NAFDAC:** National Agency for Food and Drug Administration and Control; requires registration of all commercial food products and governs food safety standards.
22. **NLTP:** National Livestock Transformation Plan; the federal policy framework targeting increased domestic poultry and livestock production in Nigeria.
23. **Notifiable disease:** a disease that must be reported to government veterinary authorities when identified; examples: Newcastle disease, HPAI; requires compulsory control measures.
24. **Price risk:** the risk that poultry prices will fall below the cost of production before the flock is sold; a major financial risk for Nigerian poultry producers.
25. **Salmonella:** a bacterial foodborne pathogen; a major food safety hazard in poultry processing; controlled by HACCP, chilling, and hygiene.
26. **SON:** Standards Organisation of Nigeria; sets Nigerian Industrial Standards (NIS) for poultry meat and egg quality.
27. **Torticollis:** twisting of the neck; a neurological sign of Newcastle disease in poultry.
28. **Welfare Quality Protocol:** a standardised flock-level welfare assessment protocol used in commercial poultry production; covers nutrition, housing, health, and behaviour.

Concept Check Questions [Series 5]

Objective Questions

1. The _____ bird market is the dominant poultry retail channel in Nigeria; it poses biosecurity risks for disease spread including HPAI. (Linked to SLO 5.1)
2. Newcastle Disease is caused by avian paramyxovirus-1 (APMV-1); mortality can reach _____ per cent in unvaccinated flocks. (Linked to SLO 5.3)
3. Foot pad _____ (FPD) is a key broiler welfare indicator; high scores indicate wet litter and poor management. (Linked to SLO 5.5)

4. HACCP (Hazard Analysis and Critical _____ Points) is mandatory for NAFDAC-registered poultry processing plants in Nigeria. (Linked to SLO 5.7)
5. The Animal Diseases (Control) Act (CAP A17 LFN 2004) authorises the Federal Ministry of Agriculture to control _____ diseases and order compulsory slaughter of infected flocks. (Linked to SLO 5.7)

Short-Answer Questions

- State three marketing channels used by Nigerian poultry producers and describe the buyer in each. (Linked to SLO 5.1)
- Describe Newcastle Disease: causative agent, signs, and control. (Linked to SLO 5.3)
- State the Five Freedoms of animal welfare. (Linked to SLO 5.5)
- State three welfare problems associated with battery cage housing of layers. (Linked to SLO 5.6)
- State four major challenges facing the Nigerian poultry industry. (Linked to SLO 5.8)

Long-Answer Questions

1. Describe the structure of the Nigerian poultry market, the major marketing channels, and the factors determining poultry prices; and describe price risk management strategies. (Linked to SLOs 5.1, 5.2)
2. Describe the major poultry diseases in Nigeria, biosecurity principles, and the design of a vaccination programme; and explain antimicrobial resistance management. (Linked to SLOs 5.3, 5.4)
3. Explain the Five Freedoms framework, welfare indicators, and welfare issues in commercial poultry; describe the Nigerian legislative framework; and explain HACCP and its application to poultry processing. (Linked to SLOs 5.5, 5.6, 5.7)

Answers to Concept Check Questions [Series 5]

Objective Questions

6. Live.
7. 100.
8. Dermatitis.
9. Control.
10. Notifiable.

Short-Answer Questions

11. (1) Farm gate / direct sale: buyer is a local trader, household consumer, or institutional buyer contacted via WhatsApp or social media. (2) Live bird market: buyer is an urban consumer purchasing a live bird for home slaughter; trader aggregates birds from multiple smallholder farms. (3) Processor to supermarket/fast food: buyer is a formal retailer or restaurant chain purchasing chilled or frozen processed chicken from an integrated processor.
12. Causative agent: Avian paramyxovirus-1 (APMV-1). Signs: torticollis (twisted neck), leg/wing paralysis, respiratory distress, greenish watery diarrhoea, sudden death; mortality up to 100% in unvaccinated flocks. Control: vaccination (live La Sota or Clone 30 and killed oil-emulsion vaccine; no treatment available for viral disease; infected flocks slaughtered in official control programmes).
13. (1) Freedom from hunger and thirst; (2) Freedom from discomfort; (3) Freedom from pain, injury, or disease; (4) Freedom to express normal behaviour; (5) Freedom from fear and distress.
14. (1) Cannot perform natural behaviours (wing-stretch, dustbath, nesting, perching); (2) Wire floor causes foot and leg problems; (3) Close confinement causes chronic behavioural frustration and stereotypic behaviour; the EU banned conventional battery cages in 2012.

15. (1) High feed cost (65-70% of production cost; volatile maize and soyabean prices); (2) Persistent Newcastle disease and other diseases in backyard flocks serving as reservoirs; (3) Inadequate cold chain (forces live bird marketing; limits market radius); (4) Competition from cheap illegally imported frozen chicken products.

Long-Answer Questions

1. Market structure: three segments — live bird markets (LBMs; dominant; consumers prefer freshly slaughtered chicken; cold chain inadequate for widespread chilled retail); formal retail (supermarkets and fast food chains; growing; supplied by integrated processors); informal cooked chicken stalls (suya, fried chicken, pepper soup). Marketing channels: integrated producers → supermarkets/fast food at contract price; semi-commercial farmers → wholesalers → LBMs; smallholders → village traders or farm gate; direct-to-consumer growing via WhatsApp and social media. Price determination factors: feed cost (65-70% of production cost; maize and soyabean prices primary driver); supply-demand balance (seasonal peaks at Christmas, Eid, Easter); import competition (illegal frozen chicken); transport and handling cost. Price risk management: forward contracts (fix price before production; requires consistent supply); diversify marketing channels (reduce single-buyer dependence); schedule production to harvest during high-demand periods; control feed cost through bulk purchase or alternative ingredients; use PAN price data and AgriTech platforms for market information to reduce information asymmetry.
2. Major diseases: Newcastle Disease (APMV-1; torticollis, respiratory distress, green diarrhoea, sudden death; up to 100% mortality unvaccinated; control by live + killed vaccination); IBD/Gumboro (birnavirus; immunosuppression, depression, trembling in 3-6 week chicks; 5-30% mortality; control by vaccination timing matched to maternal antibody decline); HPAI H5N1 (near-100% mortality; notifiable; mandatory depopulation and movement restrictions; zoonotic risk); Marek's Disease (herpesvirus; nerve paralysis, lymphomas; in-ovo or at-hatch vaccination); Coccidiosis (Eimeria; bloody diarrhoea 2-6 weeks; coccidiostats in feed or live oocyst vaccine); IB (coronavirus; respiratory and egg

quality problems; vaccination). Biosecurity: external (perimeter fence; controlled access; vehicle disinfection at gate; 3-week quarantine for incoming birds; NAFDAC-registered chick source); internal (house-specific clothing and footwear; foot baths; AIAO; rodent/wild bird control; dead bird incineration or deep burial minimum 2 m). Vaccination programme design: use appropriate vaccine strain matching field challenge; live vaccines provide mucosal immunity; killed vaccines boost systemic antibody; time to end of maternal antibody decay; maintain cold chain throughout. AMR management: antibiotics only under veterinary prescription for confirmed bacterial infection; no prophylactic use of fluoroquinolones or 3rd-generation cephalosporins; antibiotic growth promoters being phased out globally; coccidiostats remain licensed for preventive use.

3. Five Freedoms: (1) Freedom from hunger/thirst; (2) Freedom from discomfort; (3) Freedom from pain, injury, disease; (4) Freedom to express normal behaviour; (5) Freedom from fear and distress. Welfare indicators: broilers — foot pad dermatitis (FPD) 0-4 score (high = wet litter, management failure, lameness, pain); hock burn (similar to FPD); gait score 0-5 (>2 = leg problems); breast blisters (litter quality). Layers — feather cover score (poor cover = feather-pecking, increased cold stress); bone strength (osteoporosis from Ca mobilisation); mortality and culling rate; behaviour observation. Welfare issues: battery cages restrict natural behaviour (wing-stretch, dustbathing, nesting, perching); wire floors cause foot/leg injury; chronic frustration; EU banned conventional cages 2012. Broilers — leg problems (rapid muscle growth vs skeletal development imbalance); ascites/water belly (pulmonary hypertension, right-heart failure; poor ventilation exacerbates); heat stress (dominant Nigerian welfare challenge; mitigation: tunnel ventilation, evaporative cooling, reduced stocking density in hot season, cool clean water). Nigerian legislation: Animal Diseases (Control) Act CAP A17 LFN 2004 (controls notifiable diseases; authorises compulsory slaughter; movement restrictions); NAFDAC Act (registration of all commercial food products; residue limits; food safety standards); SON NIS standards (poultry meat and egg quality); Veterinary Surgeons Act (prescription requirement for veterinary drugs); NLTP (policy framework for industry growth). HACCP (seven steps): (1) hazard analysis; (2) identify CCPs; (3) establish critical limits; (4) monitor CCPs; (5) corrective action; (6) record-keeping; (7) verification. CCPs in poultry processing: chilling (<4 degrees Celsius within 4 hours;

CCP for microbial growth); drug withdrawal (7 days; CCP for residue control); ante-mortem/post-mortem inspection (CCP for disease hazard); scalding temperature (CCP for de-feathering efficiency and microbial reduction). Mandatory for NAFDAC-registered processors and export certification.

Answers to Pilot Questions [Series 5]

Part 5.1

6. Three segments: (1) Live bird markets (LBMs): the dominant segment; urban Nigerians purchase whole live chickens at LBMs, choose the bird, and have it slaughtered on-site; the preference for fresh-slaughtered chicken is cultural and driven by trust in the product; LBMs aggregate supply from hundreds of smallholder farms and provide a convenient marketplace for both buyers and sellers. (2) Processed chicken retail (supermarkets and fast food): a small but growing segment; chilled and frozen processed chicken is supplied by integrated producers such as Chi Farms, Obasanjo Farms, and Zartech to supermarkets and fast food chains (KFC, Chicken Republic); this segment requires reliable cold chain from processing plant to retail shelf. (3) Informal cooked chicken stalls: roadside suya, pepper soup, and fried chicken stalls constitute the largest volume of out-of-home poultry consumption; they purchase live birds or fresh-slaughtered birds from LBMs for daily cooking.
7. The LBM dominates for three reasons: (1) Consumer preference for transparency: Nigerian consumers, especially in urban markets, prefer to select a live bird, observe its health condition before purchase, and have it slaughtered in front of them; this is trusted as a guarantee of freshness and food safety, even though LBMs are actually major disease biosecurity risks; (2) Cold chain gap: Nigeria's electricity supply is unreliable; a chilled or frozen supply chain from processing plant to retail requires uninterrupted cold chain (refrigerated trucks, cold storage at retail); outside the major supermarket chains in Lagos and Abuja, this infrastructure does not exist reliably; (3) Price accessibility: fresh whole live bird prices are generally lower than processed and packaged chilled chicken in

supermarkets; the LBM format avoids the packaging, processing, cold chain, and marketing costs that add to the formal retail price.

8. Five factors: (1) Feed cost (maize and soyabean are the primary ingredients at 65-70% of production cost; when they rise, breakeven price rises and producers must raise the selling price or accept lower margins); (2) Supply-demand balance (when many farms harvest simultaneously, supply exceeds demand and prices fall; during high-demand festive periods, prices spike above production cost); (3) Seasonal demand cycles (Christmas, Eid-el-Adha, Easter, and school resumption create predictable demand peaks; school holiday periods reduce institutional demand and depress prices); (4) Import competition (illegal importation of European or Brazilian frozen chicken at below-cost prices — often subsidised in origin countries — depresses domestic market prices when it enters LBMs); (5) Transport and handling costs (fuel prices and road quality determine the cost of moving birds from farm to market; high transport costs reduce the farm-gate price the producer receives).
9. Three strategies: (1) Forward contracts: the producer negotiates a supply agreement with an institutional buyer (school, hospital, hotel, fast food chain, or supermarket) before placing the flock; the contract specifies price, volume, quality standard, and delivery schedule; this eliminates price uncertainty for the production cycle but requires the producer to consistently deliver the agreed specification; failure to deliver forfeits the contract and may incur penalties. (2) Marketing channel diversification: selling to multiple buyers (LBM traders, supermarket buyers, direct consumers, and institutional buyers simultaneously) ensures that if one channel experiences a price collapse, other channels sustain revenue; a producer with three or four buyer relationships is significantly more resilient to price volatility than one dependent on a single buyer. (3) Production scheduling: by timing flock placement dates to coincide with natural demand peaks, the producer harvests birds during festive season price spikes; this requires knowledge of average grow-out duration (6 weeks for broilers) and the target market event; during periods of oversupply, a producer who delays placement until the market recovers avoids selling into depressed prices.
10. Market information tools provide smallholder producers with price data from multiple markets simultaneously, reducing the information advantage that large buyers and traders

have historically exploited. Without market information, a smallholder farmer sells to the first buyer who visits the farm, accepting whatever price is offered because the farmer does not know whether a better price is available elsewhere. When the farmer subscribes to PAN price bulletins, AgriTech Nigeria price alerts, or WhatsApp trader groups, she knows the prevailing price in Onitsha, Lagos, and Aba simultaneously; she can negotiate from the same information base as the buyer, refuse a low offer and contact an alternative buyer, or delay sale for 48 hours if prices are likely to improve. This improved bargaining power directly increases farm-gate revenue without any change in production cost.

Part 5.2

11. Newcastle Disease: causative agent is Avian Paramyxovirus-1 (APMV-1), a negative-sense RNA virus classified into virulence categories from lentogenic (low) through mesogenic to velogenic (highly virulent); the velogenic viscerotropic (VVND) form is most common in Nigeria. Transmission: very efficient horizontal spread through respiratory droplets, faeces, contaminated equipment, fomites (clothing, boots, feed bags), and aerosol up to 2 km downwind from infected flocks; the virus survives on surfaces for weeks at ambient temperature. Signs: green or yellowish watery diarrhoea; severe respiratory distress (gasping, rattling); neurological signs including torticollis (twisted neck), incoordination, and paralysis of legs and wings; cyanosis of wattles and comb; sudden death; in laying flocks, sudden drop in egg production and shell quality deterioration. Control: vaccination is the only effective prevention; live lentogenic vaccines (La Sota, Clone 30) administered by eye drop, drinking water, or spray at day 1, day 10-14, and day 21-24; killed oil-emulsion vaccines administered by injection at pre-lay boost fertility of maternal antibody in the next flock; there is no antiviral treatment; affected flocks in formal control programmes are depopulated and the farm is decontaminated.
12. Gumboro disease (IBD) is particularly damaging because it specifically destroys the bursa of Fabricius, the primary immune organ of young chickens. The bursa is a lymphoid organ in the cloaca where immature B-lymphocytes are educated and matured

before seeding into peripheral lymphoid tissues; in a healthy 3 to 6 week old chick, the bursa is critical for generating the antibody-mediated immune response against all pathogens. The IBD birnavirus infects and destroys bursal lymphocytes; the resulting immunosuppression impairs the chick's ability to respond to other pathogens and to vaccination administered after the IBD infection; this creates a window of severe susceptibility to normally manageable pathogens (E. coli, Salmonella, Marek's disease) and causes vaccine failures when ND or IB vaccines are administered to birds whose immune systems have been compromised; secondary infections in the immunosuppressed birds are the leading cause of death, not the IBD virus itself.

13. Five external biosecurity measures: (1) Perimeter fencing: a physical barrier around the entire farm prevents access by unauthorised people, stray animals, and wildlife that could carry pathogens; the fence also defines the controlled access zone through which all personnel and vehicles must pass. (2) Controlled vehicle access with disinfection: all vehicles entering the farm (feed trucks, chick delivery trucks, carcass collection vehicles) must pass through a vehicle disinfection station at the farm gate; tyres and undercarriage are sprayed with disinfectant; tyres are the primary vehicle route for Salmonella and ND virus transfer between farms. (3) Visitor log and PPE requirement: all visitors are recorded in a logbook (name, company, date, farms visited in previous 48 hours); visitors from other poultry farms are excluded for 48 hours before entry; all entering personnel change into farm-supplied protective clothing and boots and dip boots in the entrance footbath. (4) Quarantine of incoming birds: all newly purchased pullets, point-of-lay hens, or breeder birds are held in a separate isolated quarantine facility (not connected to the main poultry houses) for a minimum of 21 days before integration with the resident flock; during quarantine, birds are observed for disease signs and serologically tested if indicated. (5) Chick source control: day-old chicks are sourced exclusively from NAFDAC-registered hatcheries with documented health status, Marek's vaccination certification, and Salmonella-negative parent flocks.
14. Principles guiding vaccination programme design: (1) Vaccine strain and field challenge match: the protective antigens in the vaccine must closely match those of the circulating field strain; using an La Sota strain vaccine against a genotype VII ND field virus in Nigeria provides incomplete protection because the haemagglutinin proteins differ; where

possible, vaccination challenge data from the local region should guide strain selection; (2) Timing relative to maternal antibody: day-old chicks receive maternal antibodies from the hatching egg; these maternal antibodies neutralise live vaccines given too early (within the first week), preventing the chick from developing active immunity; the first effective live vaccine dose should be timed to coincide with the predicted end of maternal antibody protection (typically day 10-14 for ND, depending on parent flock titre); (3) Vaccine viability and cold chain: live vaccines contain viable attenuated virus that must be maintained at 2-8 degrees Celsius from manufacture until use; vaccines exposed to temperatures above 25 degrees Celsius, direct sunlight, or freeze-thaw cycles lose potency and provide no immunity; the cold chain must be verified before every vaccination event; (4) Administration method: spray, eye-drop, and drinking water administration routes produce mucosal (IgA) immunity at the respiratory and digestive tract; intramuscular or subcutaneous killed vaccine injection produces systemic (IgG) immunity; both may be needed for full protection at different life stages.

15. Antimicrobial resistance (AMR) is the ability of bacteria to withstand the effects of antibiotics that would normally inhibit or kill them; it develops when bacteria are exposed to sub-lethal concentrations of antibiotics through natural selection of resistant mutants; these resistant bacteria can spread between animals, from animals to humans through food consumption or direct contact, and between humans. Prophylactic antibiotic use in poultry is a public health concern for three reasons: (1) Resistance selection in poultry bacteria: continuous low-level antibiotic exposure in poultry houses selects for antibiotic-resistant bacteria (Salmonella, Campylobacter, E. coli) that can contaminate poultry carcasses during processing and cause treatment-resistant infections in human consumers; (2) Transfer of resistance genes: antibiotic resistance genes can be transferred between bacterial species on mobile genetic elements (plasmids); resistance genes selected in poultry gut bacteria can transfer to human pathogens (Salmonella typhi, Mycobacterium tuberculosis) even without direct transmission of the animal pathogen itself; (3) Loss of last-resort antibiotics: critically important antibiotics (fluoroquinolones, carbapenem-class antibiotics) are the last line of treatment for serious human infections; their use in poultry production selects for resistant strains that, when transmitted to humans, render these treatments ineffective.

Part 5.3

1. Five Freedoms with explanation: (1) Freedom from hunger and thirst: birds must have continuous access to fresh, clean water and a nutritionally complete diet that maintains full health and productive capacity at all times; in practical terms, this means nipple drinkers or clean open drinkers that never run dry, and ad libitum access to a properly formulated and balanced compound feed throughout the production period. (2) Freedom from discomfort: birds must have access to an environment that provides thermal comfort (neither too hot nor too cold), adequate space, protection from weather extremes, and comfortable resting substrate; for broilers this means dry litter, appropriate stocking density, and effective ventilation. (3) Freedom from pain, injury, or disease: the management programme must actively prevent suffering through biosecurity, vaccination, early disease detection, and prompt veterinary treatment; beak-trimming, while itself briefly painful, is performed to prevent the more prolonged suffering of feather-pecking injury. (4) Freedom to express normal behaviour: birds must have sufficient space, appropriate facilities, and companions of their own species to perform species-specific behaviours including feeding, preening, social interaction, and rest; in practice, this is the freedom most commonly compromised in intensive commercial systems. (5) Freedom from fear and distress: birds must be handled calmly and competently; handling, catching, transport, and slaughter must minimise fear and panic; dim lighting during catching reduces flight distance and panic response.
2. Foot pad dermatitis (FPD) is inflammatory lesion development on the plantar surface (sole) of the broiler foot caused by prolonged contact with wet, ammonia-rich litter; it ranges from Score 0 (normal, intact pink pad skin with no lesions) to Score 4 (severe: deep ulceration penetrating to subcutaneous tissue, covered by a dark black or brown scab, sometimes with secondary bacterial infection and swelling). High FPD scores (3-4) indicate: (1) litter moisture is too high (caused by drinker leakage, inadequate ventilation, or excessive stocking density); (2) ammonia concentration in the litter is high; (3) contact time with wet litter is prolonged (birds are not active and mobile enough to avoid floor contact). High FPD is associated with: lameness and pain (birds walk less and spend

more time in contact with the wet litter, creating a self-worsening cycle); reduced growth performance (lame birds eat less and have lower FCR); food safety downgrading (severe FPD lesions are visible on the processed foot, and contaminated litter contaminates the carcass surface during processing, increasing Salmonella and Campylobacter risk).

3. Three welfare problems of battery cage housing: (1) Restriction of natural behaviour: a hen in a conventional battery cage with 450 cm2 of space (smaller than an A4 sheet of paper) cannot open her wings fully, dustbathe (a natural behaviour performed by all galliform birds to maintain feather condition and skin health), perch at a raised height (a natural resting and safety behaviour), or access a nest box for private egg-laying; the chronic inability to perform these behaviours causes motivation frustration, elevated corticosterone (stress hormone) levels, and development of stereotypic behaviours (repetitive purposeless actions) indicating poor mental state. (2) Physical injury from wire floor: the wire mesh floor of battery cages, while allowing faeces to fall through, causes abnormal wear and deformation of the toe nails and the plantar surface of the foot; birds cannot scratch at litter or soil to exercise foot muscles; the wire causes hyperkeratosis (overgrowth of the skin) and lesions on the breast keel bone from constant pressure against the cage floor and front mesh. (3) Osteoporosis and bone fracture: laying hens in battery cages mobilise enormous quantities of calcium for shell formation throughout a 72-week laying cycle; cage-housed hens cannot exercise normally, resulting in severe osteoporosis (bone mineral density loss) that makes the skeleton extremely fragile; fracture rates in battery cage hens at the end of the laying cycle are 20-30%, representing a significant welfare problem.
4. Two broiler welfare problems: (1) Leg health disorders: modern commercial broiler hybrids are selected for extremely rapid breast muscle growth; the rate of muscle mass gain outpaces the rate of skeletal development (bone mineralisation, tendon strength, and joint cartilage maturation); the result is that birds bearing disproportionately heavy breast muscle on an inadequately developed skeletal frame develop tibial dyschondroplasia (abnormal cartilage in the tibia), spondylolisthesis (spinal cord compression), valgus-varus deformity (twisted legs), and femoral head necrosis; these conditions cause lameness, pain, and reluctance to move; lame birds eat less, have lower FCR, and spend more time in contact with wet litter, worsening FPD. (2) Ascites (water belly): ascites is

characterised by accumulation of straw-coloured or haemorrhagic fluid in the abdominal cavity; it is caused by pulmonary hypertension triggered by the extremely high metabolic demand of the fast-growing breast muscle, which exceeds the capacity of the pulmonary vasculature to deliver oxygen; the resulting right ventricular hypertrophy and failure allows fluid to leak from the liver into the peritoneal cavity; mortality from ascites increases when houses are poorly ventilated (reduced oxygen availability), houses are at high altitude, birds are grown too fast, or ambient temperatures are very cold (cold increases metabolic rate).

5. Heat stress is the dominant welfare challenge in Nigeria because ambient temperatures regularly reach 32 to 38 degrees Celsius during the dry season; the thermoneutral zone for adult broilers is 18 to 24 degrees Celsius; above 30 degrees Celsius, broilers exhibit severe heat stress (open-beak panting, reluctance to move, reduced feed intake, elevated water consumption); sustained temperatures above 35 degrees Celsius cause mortality; layers in heat stress reduce egg production, lay thin-shelled eggs, and have increased mortality. Two mitigation strategies: (1) Tunnel ventilation with evaporative cooling pads: in closed poultry houses, high-speed fans at one end (creating 2.5-3 m/s air speed) combined with evaporative cooling pads at the inlet end can reduce internal temperature by 5 to 10 degrees Celsius below ambient; the pads use the evaporation of water to cool incoming air; at Nigerian ambient temperatures this can bring internal temperatures within the acceptable zone even on the hottest days; (2) Reduced stocking density in the hot season: the metabolic heat generated by birds in a house is directly proportional to the number of birds; reducing stocking density from the standard 13 birds/m2 to 10 or 11 birds/m2 during the March to May and October peak heat periods reduces the metabolic heat load in the house, lowers internal temperature, and improves thermal comfort for the remaining birds, even without additional ventilation investment.

Part 5.4

1. Three pieces of legislation: (1) Animal Diseases (Control) Act (CAP A17 LFN 2004): the primary federal legislation governing animal disease control in Nigeria; main provisions

include: empowering the Minister of Agriculture to declare any animal disease a notifiable disease requiring mandatory reporting within 24 hours of suspicion; authorising veterinary inspectors to enter any premises where animals are kept; authorising compulsory slaughter of infected or exposed animals with compensation; imposing movement restrictions on animals and products from affected areas; and prescribing penalties for concealing or failing to report notifiable disease outbreaks. (2) NAFDAC Act (Laws of the Federation of Nigeria): main provisions include: requiring registration of all commercially manufactured food products (including processed poultry meat, eggs, and feed additives) with NAFDAC before they can be sold; setting maximum residue limits for veterinary drugs in food; authorising inspection and product recall; prohibiting adulteration of food products; penalties for unregistered product distribution. (3) Veterinary Surgeons Act (CAP V2 LFN 2004): main provision: only persons registered with the Nigerian Veterinary Medical Association (NVMA) may practise veterinary medicine in Nigeria; veterinary prescription is required before certain drugs (antibiotics, hormones, anesthetics) can be dispensed to poultry or livestock producers.

2. HACCP (Hazard Analysis and Critical Control Points) is a systematic, science-based food safety management approach that identifies physical, chemical, and biological hazards at each step of a food production process and establishes specific preventive control measures at the points (CCPs) where those hazards can be most effectively controlled. The seven HACCP steps: (1) Conduct a hazard analysis: identify all potential physical (bone fragments, metal), chemical (antibiotic residues, cleaning agent residues), and biological (Salmonella, Campylobacter, Listeria) hazards at each step of the production and processing sequence and assess their severity and likelihood; (2) Identify Critical Control Points: determine which steps in the process are CCPs — steps where a control measure can be applied to prevent, eliminate, or reduce a food safety hazard to an acceptable level; (3) Establish critical limits: set a measurable boundary for each CCP (e.g. carcass temperature must reach below 4 degrees Celsius within 4 hours); (4) Establish monitoring procedures: define how and how often each CCP will be measured or observed (e.g. temperature probing of 5% of carcasses per hour); (5) Establish corrective actions: define what action will be taken when monitoring shows a CCP is out of control (e.g. re-chill carcasses; quarantine and investigate the batch); (6) Establish

record-keeping and documentation procedures: all monitoring data, corrective actions, and verification activities must be recorded in permanent, dated records; (7) Establish verification procedures: regular internal audits, calibration of monitoring instruments, and periodic product testing to verify that the HACCP plan is working as intended.

3. Three Critical Control Points with control limits: (1) Carcass chilling: the CCP is the chilling step immediately after evisceration; the critical limit is that the internal carcass temperature must reach below 4 degrees Celsius within 4 hours of slaughter; above 10 degrees Celsius, Salmonella, Campylobacter, and Listeria multiply exponentially; the monitoring procedure is continuous recording of chiller water or air temperature and hourly probe measurement of internal carcass temperature of a sample of birds; corrective action if the limit is exceeded is to investigate and restore the chiller and assess whether the out-of-temperature batch is safe for further processing or must be condemned. (2) Drug withdrawal period: the CCP is the pre-slaughter period; the critical limit is that a minimum of 7 days must elapse between the last administration of any regulated veterinary medicine and the slaughter of birds for human consumption; the monitoring procedure is checking medication records against the flock slaughter date; corrective action if the withdrawal period has not been observed is to delay slaughter until the withdrawal period is complete or condemn the batch. (3) Ante-mortem inspection: the CCP is the inspection of live birds at the plant entry before stunning; the critical limit is that no birds showing clinical signs of notifiable disease (APMV-1, HPAI) or systemic illness may enter the processing line; the monitoring procedure is systematic examination of all birds by the authorised inspector; corrective action is rejection and condemnation of affected birds and notification of government veterinary authorities.
4. Four major challenges: (1) High and volatile feed cost (feed is 65-70% of broiler production cost; Nigeria imports a significant proportion of soyabean and soyabean meal; maize is subject to seasonal price swings; forex devaluation increases the naira cost of imported ingredients; these uncontrollable input price movements mean that production cost can rise 30-50% between flock placement and sale without any change in production efficiency). (2) Disease burden (Newcastle disease circulates continuously in backyard village flocks across Nigeria which serve as permanent reservoirs; these unvaccinated flocks act as amplification hosts; when commercial farms breach biosecurity, a single

introduction can devastate an entire production cycle; HPAI outbreaks (2006-2007, 2015, 2021-2022) caused massive flock losses and market disruption; the national veterinary system lacks resources to control disease in the vast informal sector). (3) Inadequate cold chain (chilled or frozen poultry marketing requires unbroken refrigeration from processing plant to consumer; outside a few supermarket chains in Lagos and Abuja, this cold chain does not exist reliably; the consequence is forced reliance on live bird marketing which is inefficient, stressful to birds, and a major biosecurity risk for HPAI transmission between farms). (4) Limited access to affordable credit (commercial bank lending to poultry farms carries interest rates of 20-28% per annum with collateral requirements most smallholders cannot meet; government credit programmes such as CBN ABP cover rice, wheat, and some livestock but poultry lending is limited; the high cost of capital means that many medium-scale farmers cannot achieve the economies of scale needed to compete with large integrated producers or imported frozen chicken).

5. Four opportunities: (1) Growing domestic protein demand: Nigeria's 220 million population is growing at 2.5% per year and urbanising rapidly; urban middle-class consumers are shifting from plant-based to animal-protein diets; per capita poultry consumption is rising; this expanding market provides structural demand growth that an improved domestic industry can serve. Exploitation strategy: invest in processing and cold chain infrastructure to supply formal retail; develop branded products that command premium prices from health-conscious urban consumers. (2) Government import restriction: Nigeria has periodically banned or restricted importation of poultry products; the import ban protects domestic producers from cheap foreign competition and is a direct market opportunity. Exploitation strategy: lobby through PAN to maintain and strengthen import restrictions while simultaneously increasing domestic production capacity to fill the protected market. (3) Alternative and cheaper feed ingredients: black soldier fly (Hermetia illucens) larvae (40-45% crude protein; produced on organic waste) and duckweed (Lemna spp.; 25-45% protein) can partially or fully replace expensive fishmeal and soyabean in poultry diets; Nigerian university research programmes and IITA are generating evidence on their efficacy. Exploitation strategy: establish commercial-scale insect or duckweed protein production units close to major poultry clusters; formulate and certify alternative protein-based poultry feeds. (4) Digital and

agri-tech solutions: farm monitoring sensors, automated environmental control systems, digital disease diagnostic tools (e.g. AI-based mortality camera monitoring), and e-commerce platforms are reducing management costs, improving performance, and connecting producers directly with consumers. Exploitation strategy: adopt low-cost GSM-connected environmental monitoring (temperature, humidity, CO2) to prevent performance losses; use direct digital marketing to access premium institutional and urban consumer buyers.

References and Attributions [Series 5]

Textual References (Books and External Sources)

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2. Farm Animal Welfare Council (FAWC). (1979). Press statement on the five freedoms. FAWC.
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Figures, Plates, Tables, and Boxes

1. Figure 5.1: Nigerian poultry marketing channels flow diagram Attribution: AI generated. Suggested OER search string: "Nigeria poultry marketing channels live bird market supermarket processor OER diagram".
2. Box 5.1: Major Nigerian poultry diseases summary Attribution: AI generated. Suggested OER search string: "major poultry diseases Nigeria Newcastle Gumboro avian influenza Marek coccidiosis OER box".

3. Figure 5.2: Foot pad dermatitis scoring photograph Attribution: AI generated. Suggested OER search string: "foot pad dermatitis scoring broiler welfare indicator photograph OER".
4. Figure 5.3: HACCP seven principles flow diagram Attribution: AI generated. Suggested OER search string: "HACCP seven principles poultry processing diagram food safety OER".
5. Box 5.2: Nigerian poultry industry challenges and opportunities Attribution: AI generated. Suggested OER search string: "Nigeria poultry industry challenges opportunities feed cost cold chain demand import OER box".