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AGE 408

ANIMAL PRODUCTS HANDLING, PROCESSING AND STORAGE

Course code: AGE 408

Course title: Animal Products Handling, Processing and Storage

Course credit load: 2 Units

Series 1: Evolution and Importance of Animal Products Technology

- **Part 1.1: Definition and Scope of Animal Products Technology**
  - Sub Part 1.1.1: Definition and classification of animal products
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Introduction

Animal products — meat, milk, eggs, hides, and their many derivatives — are among the most nutritionally dense and economically significant commodities in agriculture. Yet they are also among the most perishable. Without appropriate technology for handling, processing, and storage, a large proportion of these products would be lost between production and consumption, representing a direct loss of food, income, and nutritional value.

This Series introduces the definition and classification of animal products, the scope of the technology used to handle them, their economic importance, and the physiological basis for post-harvest deterioration. These foundations underpin every subsequent topic in the course and establish the framework for understanding why processing is necessary, what it achieves, and how it is regulated.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define animal products technology and classify the major categories of animal products (Linked to Part 1.1),
- **SLO 1.2** describe the scope and components of animal products technology and identify career opportunities (Linked to Part 1.1),
- **SLO 1.3** describe the historical development of animal products technology from traditional methods to industrial processing (Linked to Part 1.2),
- **SLO 1.4** explain the development of the Nigerian animal products industry (Linked to Part 1.2),
- **SLO 1.5** explain the economic importance of animal products technology including food security, income generation, and value addition (Linked to Part 1.3),
- **SLO 1.6** describe the post-harvest physiological changes in animal products and explain why they lead to spoilage (Linked to Part 1.4),
- **SLO 1.7** describe the general principles of storage and the regulatory framework governing animal product safety in Nigeria (Linked to Part 1.4).

1.1 Definition and Scope of Animal Products Technology

1.1.1 Definition and classification of animal products

Animal products technology is the science and practice of handling, processing, preserving, storing, and marketing products derived from domesticated and wild animals to maintain their safety, quality, and economic value from the point of production to the final consumer. It encompasses all operations applied to primary products (meat, milk, eggs) and secondary products (hides, wool, feathers, bone meal, blood meal) to extend shelf life and add value.

Animal products are classified by their source and nature. Primary food products include meat (from cattle, sheep, goats, pigs, poultry), milk and dairy derivatives (butter, cheese, yoghurt), and eggs. Non-food primary products include hides and skins (leather), wool, feathers, and horns. By-products and secondary products include blood meal, bone meal, tallow, feather meal, and offal. Each category has distinct composition, spoilage pathways, and processing requirements.

Fill in the blank: Animal products technology encompasses handling, processing, preserving, storing, and ________ of products derived from animals to maintain their safety, quality, and economic value to the consumer.

1.1.2 Scope and components of animal products technology

The scope of animal products technology covers five main areas. Slaughter and primary processing: converting live animals into carcasses and separating usable products (meat cuts, offal, hides). Secondary processing and value addition: manufacturing products such as sausages, ham, butter, cheese, and dried eggs from the primary products. Preservation: applying physical (heat, cold, radiation) or chemical (salting, curing) methods to extend shelf life. Storage: maintaining conditions (temperature, humidity, atmosphere) that slow deterioration.

Marketing and distribution: moving safe, quality products from processor to consumer through appropriate cold chain or ambient distribution networks. The discipline draws on food science, microbiology, biochemistry, engineering, and economics. In Nigeria, the scope extends from large integrated meat processing plants in Kano, Kaduna, and Lagos to millions of informal processors (butchers, suya sellers, milk fermenters, egg traders) whose practices significantly influence the safety and quality of the animal-protein food supply.

Fill in the blank: The five main areas of animal products technology are slaughter and primary processing, secondary processing and value addition, preservation, storage, and ________ and distribution.

1.1.3 Career opportunities in animal products technology

Graduates with competency in animal products technology can pursue careers across a wide range of organisations and sectors. In government and regulation: meat inspection officer (NAFDAC, state ministries of agriculture); food safety auditor; veterinary public health officer; standards and quality control inspector (SON). In industry: quality assurance manager in a meat processing plant or dairy; product development technologist; cold chain and logistics manager; food safety consultant.

In research and academia: food scientist in universities and research institutes (FIIRO, NIHORT, IITA); animal scientist specialising in product quality; extension officer for value-chain development. In entrepreneurship: establishing and managing an abattoir, dairy processing unit, egg grading and packing centre, or hide and skin tanning operation. The growing Nigerian food processing sector, driven by urbanisation and the rising formal retail and food service market, creates expanding demand for qualified professionals in these roles.

Fill in the blank: The Federal Institute of Industrial Research Oshodi (________) and the Nigerian Institute of Animal Science (NIAS) are among the key research institutions supporting animal products technology in Nigeria.

Pilot questions 1.1

1. Define animal products technology and state the five areas of its scope.
2. Classify animal products into primary food products, non-food primary products, and by-products, giving two examples of each.
3. Name five career paths available to graduates of animal products technology.
4. Explain the difference between primary and secondary processing with one example of each.

5. Explain why the discipline of animal products technology draws on multiple scientific fields.

1.2 Historical Evolution of Animal Products Technology

1.2.1 Pre-industrial and traditional processing methods

The earliest animal product processing consisted of drying (sun-drying of fish and meat), salting (rubbing salt into meat and fish to draw out moisture), and smoking (exposing meat or fish to wood smoke to dry and add antimicrobial compounds). These methods were empirically developed over thousands of years before the microbial basis of spoilage was understood. Evidence of drying, salting, and smoking of meat and fish dates to ancient Egypt, Rome, and pre-colonial sub-Saharan Africa.

Traditional Nigerian animal product processing: kilishi (dried, spiced meat from the north; a form of jerky produced from thinly sliced beef, marinated in groundnut paste and spices, and sun-dried); suya (spiced grilled beef or chicken skewers, smoke-cooked over open flames); wara (traditional West African soft cheese from cow or goat milk, coagulated with Calotropis latex); nono (fermented soured milk); and fried or smoked fish (a critical protein source throughout southern Nigeria). These products represent millennia of empirical knowledge of preservation.

Fill in the blank: Kilishi is a traditional Nigerian dried spiced meat product from the north; it is produced by marinating thinly sliced beef in ________ paste and spices, then sun-drying until shelf-stable.

Figure 1.1: Photographs of traditional Nigerian animal product processing methods

1.2.2 Industrial revolution and modern processing

The scientific understanding of microbial spoilage (Pasteur, 1850s-1860s) and the systematic development of food preservation technology transformed animal products processing into a modern industry. Key milestones: Nicolas Appert invented heat sterilisation in cans (1809); mechanical refrigeration was invented (1850s-1860s), making cold chain transport possible; pasteurisation of milk (1864) was standardised; and large-scale meat packing and canning industries emerged in Chicago (USA) and London (UK) in the late 19th century.

The 20th century brought rapid industrialisation: spray drying of milk powder (1900s); vacuum packaging for extended shelf life (1950s); continuous pasteurisation and UHT sterilisation of milk (1960s-1970s); irradiation of food (1960s onwards); modified atmosphere packaging (1980s); and HACCP (Hazard Analysis and Critical Control Points) as the standard food safety management system (widely adopted from 1990s). Each advance extended the reach of safe animal products to wider populations over greater distances.

Fill in the blank: Nicolas Appert invented heat sterilisation in ________ in 1809; Louis Pasteur's discovery of microbial spoilage in the 1850s-1860s provided the scientific basis for modern food preservation technology.

1.2.3 Development of the Nigerian animal products industry

Pre-colonial Nigeria had well-established indigenous processing traditions: kilishi and dambun nama (shredded dried meat) in the north; smoked and dried fish along the Niger River and Atlantic coast; wara cheese and nono fermented milk in the cattle-keeping Middle Belt and north. Colonial trade introduced industrial canning and refrigeration technology in the early 20th century, primarily for export of hides, skins, and groundnut products rather than for domestic food processing.

Post-independence development (1960s-1980s): government investment in abattoirs (Kano, Kaduna, Lagos, Ibadan); dairy processing plants (Frisians using imported exotic cattle at government farms); and fish processing facilities. The structural adjustment programme (1986) disrupted formal sector operations; many government-owned processing facilities collapsed. Recovery from the 1990s was primarily private sector-driven: large meat processors (Zartech, Chi Farms), dairy companies (FanMilk, Hollandia/CHI, Promasidor), and a growing artisanal processing sector.

Fill in the blank: The structural adjustment programme of ________ disrupted Nigeria's formal animal products processing sector; recovery from the 1990s was driven primarily by private sector investment in meat, dairy, and food processing.

Pilot questions 1.2

1. Describe three traditional Nigerian animal product processing methods and explain the preservation principle behind each.
2. State three major milestones in the development of modern animal products processing technology.

3. Explain the significance of Pasteur's work to the development of animal products technology.
4. Describe the development of the Nigerian animal products processing industry from pre-colonial times to the present.
5. Explain how industrial refrigeration changed the marketing and distribution of animal products globally.

1.3 Economic Importance of Animal Products Technology

1.3.1 Contribution to food security and nutrition

Animal products are the most concentrated source of complete protein, essential fatty acids, fat-soluble vitamins (A, D, E, K), and bioavailable minerals (iron, zinc, calcium, phosphorus) in the human diet. A single egg provides approximately 6 g of high biological value protein and all essential amino acids. Milk provides calcium essential for bone development. Red meat provides haem iron — the most bioavailable form — critical for prevention of iron-deficiency anaemia, which affects approximately 68 per cent of Nigerian women of reproductive age.

Processing technology extends the shelf life of perishable animal products, making them available year-round and across geographic distances that fresh products cannot reach. Canning, drying, and fermentation convert seasonal surpluses into storable commodities. This temporal and spatial extension of availability directly improves national food security: a Nigerian farmer in Adamawa who produces milk in the wet season can have her production pasteurised, packed, and distributed to Lagos consumers six months later. Without processing technology, that nutritional value is lost to spoilage.

Fill in the blank: Red meat provides haem ________ — the most bioavailable form of dietary iron — which is critical for preventing iron-deficiency anaemia that affects approximately 68 per cent of Nigerian women of reproductive age.

1.3.2 Economic value and income generation

The animal products processing sector generates economic value through employment, revenue, and foreign exchange. Direct employment: Nigeria's meat processing, dairy, and poultry processing industries directly employ an estimated 500,000 to 1 million formal and informal sector workers along the value chain. Indirect employment: feed production, veterinary services, transport, cold chain, packaging, and retail of animal products collectively employ many times more. The livestock sector contributes approximately 5 to 8 per cent of national GDP directly; animal products processing amplifies this further.

Foreign exchange: hides and skins have historically been a significant export commodity, particularly from northern Nigeria (Kano, Sokoto, Maiduguri); processed Sokoto Red goat leather (Moroccan leather) commands premium prices in European fashion markets. Aquaculture products (dried crayfish, smoked fish) and some dairy products generate regional export income. Import substitution: expanding domestic dairy and meat processing capacity reduces Nigeria's annual import bill for dairy products (currently over USD 1 billion per year in dairy alone), retaining foreign exchange within the economy.

Fill in the blank: Nigeria's annual import bill for dairy products exceeds USD ________ billion; expanding domestic dairy processing capacity would reduce this import dependency and retain foreign exchange in the economy.

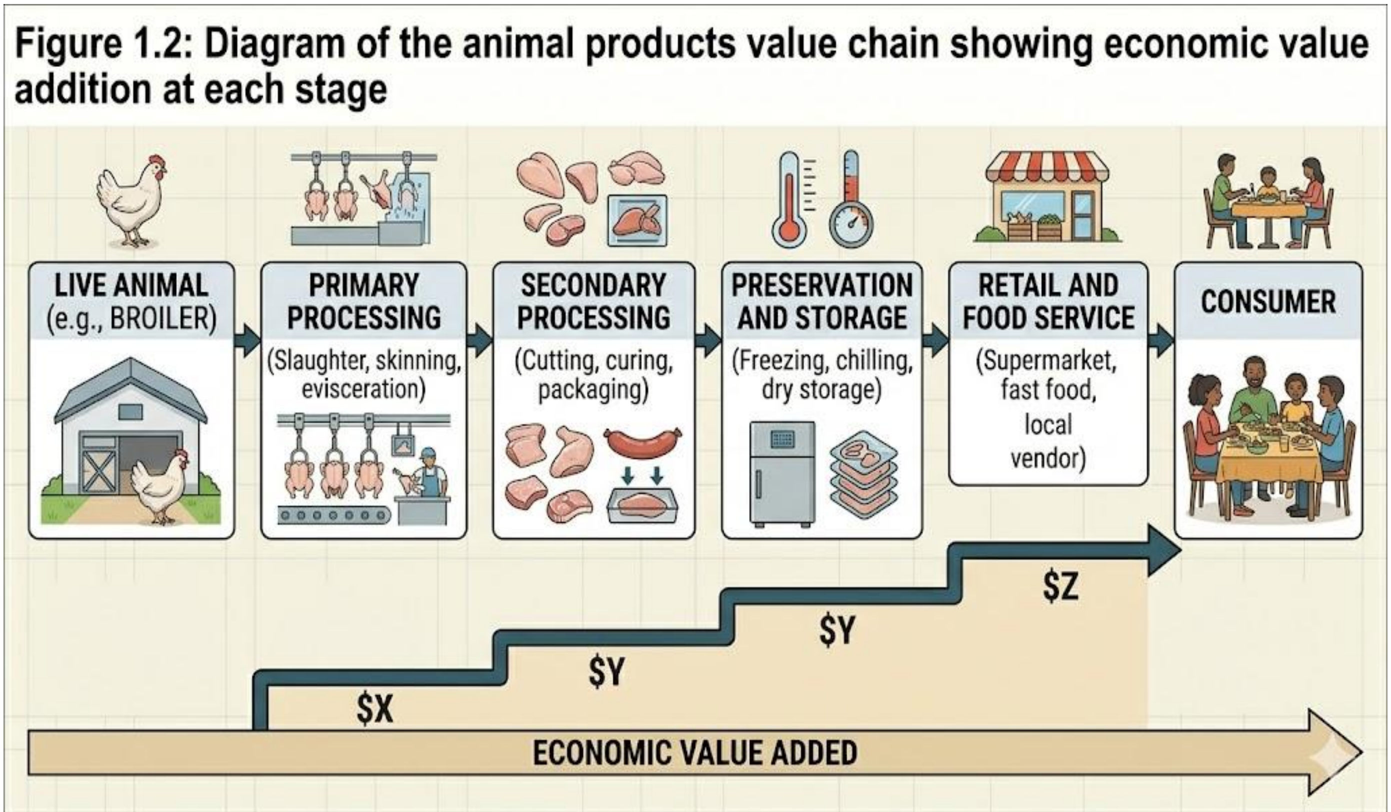

Figure 1.2: Diagram of the animal products value chain showing economic value addition at each stage

1.3.3 Value addition and the processing premium

Value addition is the increase in the market price of an animal product achieved through processing, packaging, branding, or quality certification beyond its raw commodity price. A litre of raw milk sold at the farm gate fetches approximately NGN 200 to 400; the same milk pasteurised, packaged in a branded carton, and sold in a Lagos supermarket retails for NGN 700 to 1,200. The difference (the processing premium) compensates for the cost of processing and generates profit for the processor, but also signals to the producer that quality raw material is worth more.

Processing premium examples in Nigeria: fresh beef at abattoir gate (NGN 2,500/kg) versus packaged sausage (NGN 4,500 to 6,000/kg from the same raw material); raw cow hide versus finished Kano leather (tanned, dyed, and graded; value increases by 300 to 500%); raw fish versus smoked catfish (retail price 2 to 3 times raw price). The processing premium incentivises investment in processing infrastructure and drives the formalisation of the animal products industry. NAFDAC certification and SON grading further increase value by assuring buyers of product safety and quality.

Fill in the blank: The ________ premium is the increase in market price achieved through processing; pasteurised branded milk in Lagos retails at 2 to 5 times the farm-gate price of raw milk, compensating the processor and incentivising investment in processing infrastructure.

Pilot questions 1.3

1. Explain four ways in which animal products contribute to human nutrition.
2. Explain how processing technology improves food security.
3. Describe three ways in which the animal products processing sector generates economic value in Nigeria.
4. Define value addition and calculate the approximate processing premium for raw milk in Nigeria.
5. Explain why hides and skins processing is economically important for northern Nigeria.

1.4 Post-Harvest Physiology and Principles of Animal Products Handling

1.4.1 Post-harvest physiology of animal products

At slaughter, the animal's homeostatic mechanisms cease and the carcass begins a series of predictable biochemical changes. Rigor mortis: within 1 to 4 hours post-slaughter (depending on species and temperature), muscle ATP is depleted, and actin and myosin permanently cross-link, causing the muscle to stiffen; cattle reach full rigor at 12 to 24 hours; poultry at 2 to 4 hours. Resolution of rigor (conditioning): proteolytic enzymes (calpains) gradually break down myofibrillar proteins over several days, tenderising the meat (ageing or conditioning; 7 to 14 days for beef at 1 to 4 degrees Celsius).

pH decline: glycolysis continues post-mortem, converting muscle glycogen to lactic acid; pH falls from 7.4 to 5.4 to 5.8 (ultimate pH). This pH drop is important for meat safety (inhibits many pathogens) and quality (affects water-holding capacity, colour, and texture). For milk: once secreted, milk is immediately colonised by environmental bacteria; without rapid cooling (below 4 degrees Celsius) bacterial multiplication proceeds exponentially. Eggs: the cuticle seals the pores; once removed by washing or abrasion, bacterial entry accelerates; internal quality declines through CO2 loss and moisture evaporation.

Fill in the blank: Rigor mortis occurs when muscle ________ is depleted post-slaughter, causing permanent actin-myosin cross-linking and muscle stiffening; it resolves over several days through proteolytic enzyme activity (conditioning).

Product	**Key Changes**	**Notes**
Beef	Rigor mortis 12–24 hrs; ultimate pH 5.4–5.8; conditioning 7–14 days at 1–4 °C	Aging improves tenderness
Poultry	Rigor mortis 2–4 hrs; ultimate pH 5.7–6.0; shelf life 1–2 days fresh	Short shelf life unless chilled/frozen
Pork	Rigor mortis 4–6 hrs; prone to PSE (pale, soft, exudative) if stressed	Stress management critical
Milk	Rapid bacterial multiplication above 4 °C; acidity rises as lactobacilli ferment lactose	Requires strict cold chain
Eggs	CO_2 loss raises albumen pH; air cell enlarges; yolk membrane weakens; quality decline fastest above 20 °C	Refrigeration slows deterioration

Box 1.1: Summary of post-harvest physiological changes in major animal products

1.4.2 General principles of storage

The general objective of storage is to retard or prevent the three main causes of animal product deterioration: microbial growth (bacteria, moulds, yeasts multiply under favourable temperature, moisture, and nutrient conditions); enzymatic activity (endogenous enzymes in muscle, milk, and egg continue to act post-harvest, causing breakdown of proteins, fats, and carbohydrates); and chemical reactions (oxidation of fats causing rancidity; Maillard browning; haem oxidation causing colour change in meat).

Guiding principles for storage: temperature control (most important — refrigeration slows microbial growth and enzymatic activity; freezing arrests them; each 10-degree Celsius rise approximately doubles the rate of bacterial growth); humidity control (high humidity favours mould growth; low humidity causes desiccation — both are undesirable); modified atmosphere (reducing O_2 and increasing CO_2 inhibits aerobic spoilage organisms and slows oxidation); and exclusion of contaminants (pests, dust, chemicals, light). The correct combination of these controls is product-specific.

Fill in the blank: Each 10-degree Celsius rise in temperature approximately ________ the rate of bacterial growth; refrigeration is the most important single factor in slowing animal product spoilage.

1.4.3 Regulatory framework and safety standards

In Nigeria, animal product safety and quality are governed by several legislative instruments. The NAFDAC Act requires registration and safety certification of all commercially processed food products. The Animal Diseases (Control) Act governs animal health pre-slaughter. The Standards Organisation of Nigeria (SON) sets Nigerian Industrial Standards (NIS) for specific products including milk, eggs, and meat. The National Agency for Food Safety (in some states operating as State Food Safety Programmes) enforces processing hygiene standards at local abattoirs and markets.

International standards relevant to Nigerian animal product processors: the Codex Alimentarius Commission (FAO/WHO) sets internationally recognised food safety standards that underpin market access; ISO 22000 (food safety management systems); HACCP (Hazard Analysis and Critical Control Points) is required for formal export and for major retail chains sourcing processed animal products in Nigeria. Compliance with these standards is a prerequisite for accessing formal urban retail, institutional buyers, and export markets; non-compliance results in product rejection, business closure, or legal prosecution.

Fill in the blank: The ________ Alimentarius Commission (FAO/WHO) sets internationally recognised food safety standards; compliance is a prerequisite for Nigerian animal product processors seeking access to export markets or formal retail chains.

Pilot questions 1.4

1. Explain what rigor mortis is, when it occurs, and what resolves it.
2. Describe the post-harvest physiological changes in fresh milk and explain their significance for processing.
3. State three main causes of animal product deterioration and explain how storage conditions control each.
4. Explain the role of NAFDAC and SON in regulating animal product safety and quality in Nigeria.
5. Explain what HACCP is and why it is required for animal product processors seeking formal market access.

Series Summary

This Series introduced the definition, scope, history, economic importance, and physiological basis of animal products technology. Animal products (primary food products, non-food products, and by-products) are handled, processed, preserved, stored, and marketed through five main technological areas. Traditional Nigerian processing (kilishi, suya, wara, smoked fish, nono) represents centuries of empirical preservation knowledge; modern industrial technology (refrigeration, pasteurisation, canning, vacuum packaging, HACCP) emerged from the 19th century onwards. Nigeria's processing sector developed through colonial-era government investment, collapse under the SAP (1986), and private sector recovery from the 1990s.

Animal products contribute to food security (complete protein, haem iron, vitamins, minerals), economic value (employment, GDP, foreign exchange, import substitution), and value addition (processing premium of 2 to 5 times raw commodity price). Post-harvest physiology: rigor mortis (ATP depletion, actin-myosin cross-linking; 2-24 hours by species), pH decline (glycolysis to lactic acid; ultimate pH 5.4-5.8 for beef), and conditioning (proteolytic tenderisation over 7-14 days). Storage principles: temperature, humidity, modified atmosphere, contaminant exclusion. Regulatory framework: NAFDAC, SON, HACCP, Codex Alimentarius. By completing this Series, you should achieve all seven SLOs (1.1 to 1.7).

Glossary of Terms

- **Animal products technology:** the science and practice of handling, processing, preserving, storing, and marketing products derived from animals to maintain their safety, quality, and economic value.
- **By-product:** a secondary or incidental product derived from the processing of a primary animal product; examples include blood meal, bone meal, tallow, feather meal, and offal.
- **Codex Alimentarius:** a collection of internationally recognised standards, codes of practice, and guidelines for food safety set by the FAO/WHO Codex Alimentarius Commission; underpins global food trade.
- **Conditioning (ageing):** the post-rigor period during which proteolytic enzymes (calpains) break down myofibrillar proteins, tenderising meat; 7-14 days for beef at 1-4 degrees Celsius.
- **Dambun nama:** a traditional northern Nigerian dried shredded meat product; meat is boiled, shredded, and dried; used as a storable protein source.
- **FIIRO:** Federal Institute of Industrial Research Oshodi; a key Nigerian research institution supporting food and animal products processing technology.
- **HACCP:** Hazard Analysis and Critical Control Points; a systematic preventive food safety management system; required for NAFDAC-registered processors and formal market access.
- **Haem iron:** iron bound within the haem molecule in red meat; highly bioavailable compared with non-haem iron in plant foods; important in preventing iron-deficiency anaemia.
- **Kilishi:** a traditional northern Nigerian dried spiced beef product; thinly sliced meat marinated in groundnut paste and spices, then sun-dried; a form of jerky.
- **Maillard browning:** a chemical reaction between amino acids and reducing sugars during heating; produces the characteristic brown colour and cooked flavour of meat and dairy products.
- **NAFDAC:** National Agency for Food and Drug Administration and Control; requires registration and safety certification of all commercially processed food products in Nigeria.

- **Nono:** traditional northern Nigerian fermented soured milk; naturally fermented by lactic acid bacteria; sold in calabashes or plastic sachets by Fulani traders.
- **Processing premium:** the increase in market price of an animal product achieved through processing, packaging, branding, or quality certification beyond its raw commodity price.
- **Rigor mortis:** the stiffening of muscles shortly after death caused by depletion of ATP and permanent cross-linking of actin and myosin; occurs 2-24 hours post-slaughter depending on species and temperature.
- **SON:** Standards Organisation of Nigeria; sets Nigerian Industrial Standards (NIS) for specific animal products including milk, eggs, and meat.
- **Suya:** a popular Nigerian spiced grilled meat (beef, chicken, or offal) cooked on skewers over open charcoal or wood fire; a street food tradition from the north.
- **Ultimate pH:** the final pH reached in muscle post-slaughter after glycolysis has exhausted glycogen reserves; normal range 5.4-5.8 for beef; higher pH indicates DFD (dark, firm, dry) meat.
- **Value addition:** any process that increases the economic value of a raw agricultural commodity; in animal products, this includes processing, packaging, branding, and quality certification.
- **Wara:** traditional West African soft white cheese made by coagulating cow or goat milk with Calotropis leaf latex or citrus; consumed fresh; important protein source in the Middle Belt and north.

Concept Check Questions [Series 1]

Objective Questions

1. Animal products technology covers handling, processing, preserving, storing, and ________ of products derived from animals. (Linked to SLO 1.1)
2. Nicolas Appert invented heat sterilisation in ________ in 1809; this was a key milestone in the development of modern food preservation. (Linked to SLO 1.3)

3. Rigor mortis occurs when muscle ________ is depleted post-slaughter, causing permanent actin-myosin cross-linking and muscle stiffening. (Linked to SLO 1.6)
4. Each 10-degree Celsius rise in temperature approximately ________ the rate of bacterial growth; refrigeration is the most critical storage control measure. (Linked to SLO 1.7)
5. The ________ Alimentarius Commission sets internationally recognised food safety standards; compliance is required for export market access by Nigerian processors. (Linked to SLO 1.7)

Short-Answer Questions

6. Define animal products technology and classify animal products into three categories with two examples each. (Linked to SLO 1.1)
7. State three traditional Nigerian animal product processing methods and the preservation principle of each. (Linked to SLO 1.3)
8. Explain three ways animal products contribute to food security and nutrition in Nigeria. (Linked to SLO 1.5)
9. Describe rigor mortis: what causes it, when it occurs, and how it resolves. (Linked to SLO 1.6)
10. State three guiding principles for the storage of animal products and explain the purpose of each. (Linked to SLO 1.7)

Long-Answer Questions

11. Define animal products technology, describe its scope, and identify the career opportunities it offers. (Linked to SLOs 1.1, 1.2)
12. Describe the historical development of animal products technology from traditional methods to modern industry, with specific reference to Nigeria. (Linked to SLOs 1.3, 1.4)
13. Explain the economic importance of animal products technology and describe the post-harvest physiological changes that make processing necessary; and describe the regulatory framework governing animal product safety in Nigeria. (Linked to SLOs 1.5, 1.6, 1.7)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. Marketing.
2. Cans.
3. ATP.
4. Doubles.
5. Codex.

Short-Answer Questions

6. Animal products technology is the science and practice of handling, processing, preserving, storing, and marketing products derived from animals to maintain safety, quality, and economic value. Categories: primary food products (meat, milk, eggs); non-food primary products (hides/skins, wool, feathers); by-products (blood meal, bone meal, tallow).
7. Kilishi (drying and spicing: removes moisture and adds antimicrobial compounds via groundnut paste and spices); suya (smoking and grilling: heat kills pathogens and desiccation reduces water activity); smoked fish (smoking: drying, antimicrobial phenols from wood smoke, and heat combine to extend shelf life).
8. Complete protein supply (animal products provide all essential amino acids in high biological value protein); haem iron for anaemia prevention (68% of Nigerian women of reproductive age are anaemic; red meat provides highly bioavailable haem iron); shelf life extension (canning, drying, and fermentation convert seasonal surpluses into storable commodities available year-round across Nigeria).
9. Rigor mortis is caused by depletion of ATP in muscle post-slaughter, which prevents the actin-myosin complex from dissociating, causing permanent muscle contraction and stiffening. It begins 1-4 hours post-slaughter and is complete by 12-24 hours in cattle; 2-4 hours in poultry. It resolves through conditioning: proteolytic enzymes (calpains) gradually break down myofibrillar proteins over 7-14 days, tenderising the meat.
10. Temperature control (refrigeration slows microbial growth and enzymatic activity; the primary and most important storage control); humidity control (high humidity promotes mould; low humidity causes desiccation — both accelerate spoilage); modified atmosphere (reducing O2 and increasing CO2 inhibits aerobic spoilage organisms and slows lipid oxidation).

Long-Answer Questions

11. Definition: the science and practice of handling, processing, preserving, storing, and marketing products derived from domesticated and wild animals to maintain safety, quality, and economic value. Scope (5 areas): (1) slaughter and primary processing (converting live animals to carcasses; separating meat, offal, hides); (2) secondary processing and value addition (manufacturing sausages, cheese, dried eggs); (3) preservation (heat, cold, salting, smoking, radiation); (4) storage (temperature, humidity, atmosphere control); (5) marketing and distribution (cold chain to consumer). Draws on food science, microbiology, biochemistry, engineering, and economics. Career opportunities: government (NAFDAC meat inspector, SON quality auditor, veterinary public health officer); industry (quality assurance manager, product development technologist, cold chain manager, food safety consultant); research (FIIRO food scientist, university lecturer, extension officer); entrepreneurship (abattoir operator, dairy processor, egg grading centre, hide and skin tanner). Demand growing with urbanisation and formal retail expansion.
12. Traditional methods: drying, salting, and smoking date to ancient Egypt and pre-colonial Africa; no understanding of microbiology; empirically effective. Nigerian traditional products: kilishi (sun-dried spiced beef; north); dambun nama (boiled, shredded, dried meat); suya (smoke-grilled spiced meat); wara (Calotropis-coagulated soft cheese); nono (fermented soured milk); smoked/dried fish (Niger Delta, riverine communities). Industrial revolution milestones: Pasteur's microbial spoilage discovery (1850s); Appert's canning (1809); mechanical refrigeration (1850s-60s); pasteurisation of milk (1864); large-scale meat packing (Chicago, late 19th century); spray drying (1900s); vacuum packaging (1950s); UHT milk (1960s-70s); HACCP (1990s widespread adoption). Nigerian industry development: pre-colonial processing traditions; colonial era — government abattoirs (Kano, Kaduna, Lagos, Ibadan), exotic breed dairy (government farms), canned products for export; post-independence (1960s-80s) — government dairy plants, formal abattoirs; SAP disruption (1986) — many government processing units collapsed; post-1990s private sector recovery: Zartech, Chi Farms (meat/poultry), FanMilk, Hollandia/CHI, Promasidor (dairy); growing artisanal sector.
13. Economic importance: food security (complete protein, haem iron for anaemia, fat-soluble vitamins; processing extends temporal and spatial availability turning seasonal surplus into storable commodities); income and employment (500,000-1 million direct formal/informal jobs;

indirect employment in feed, transport, retail; 5-8% GDP from livestock, amplified by processing); foreign exchange (hides/skins export — Sokoto Red leather commands premium in European fashion; import substitution — Nigeria imports >USD 1 billion dairy/year; domestic processing reduces this); value addition (processing premium: raw milk NGN 200-400/L vs branded pasteurised NGN 700-1,200; raw beef NGN 2,500/kg vs sausage NGN 4,500-6,000). Post-harvest physiology: rigor mortis (ATP depletion; actin-myosin permanent cross-linking; stiffening; 12-24 hours cattle, 2-4 hours poultry); pH decline (glycolysis depletes glycogen; lactic acid produced; pH falls 7.4 to 5.4-5.8; inhibits pathogens, affects water-holding and colour); conditioning (proteolysis by calpains; tenderisation over 7-14 days at 1-4 degrees Celsius); milk (exponential bacterial growth above 4 degrees Celsius); eggs (CO_2 loss, air cell growth, yolk membrane weakening at ambient temperature). Storage principles: temperature (most important; refrigeration slows; freezing arrests; 10-degree rule doubles bacterial rate); humidity (high = mould; low = desiccation); modified atmosphere (O_2 reduction, CO_2 increase); exclusion of contaminants. Regulatory framework: NAFDAC Act (commercial food product registration and safety certification); Animal Diseases (Control) Act (animal health pre-slaughter); SON NIS standards (product-specific quality standards); HACCP mandatory for NAFDAC-registered processors and formal market access; Codex Alimentarius underpins export market compliance.

Answers to Pilot Questions [Series 1]

Part 1.1

1. Definition: the science and practice of handling, processing, preserving, storing, and marketing products derived from animals to maintain safety, quality, and economic value from production to the final consumer. Five scope areas: (1) slaughter and primary processing (converting live animals into carcasses; separating meat, offal, and hides); (2) secondary processing and value addition (manufacturing value-added products such as sausages, ham, butter, and cheese from primary products); (3) preservation (applying physical and chemical methods to extend shelf life); (4) storage (maintaining temperature, humidity, and atmosphere conditions that slow deterioration); (5) marketing and distribution (moving safe, quality products from processor to consumer through appropriate distribution networks).
2. Primary food products: meat (beef, goat meat, pork, poultry) and milk and dairy derivatives (butter, cheese, yoghurt) and eggs — these are directly consumed as food after minimal or

significant processing. Non-food primary products: hides and skins (leather raw material) and wool, feathers, and horns — these have commercial or industrial uses but are not eaten. By-products and secondary products: blood meal (high-protein animal feed ingredient), bone meal (animal feed and fertiliser), tallow (soap and candle manufacture), feather meal (animal feed), and offal (edible internal organs such as liver, kidney, tripe).

3. Five career paths: (1) NAFDAC meat inspection officer or food safety auditor in government (inspecting abattoirs, processing plants, and markets for compliance with food safety standards); (2) quality assurance manager or product development technologist in a private meat processing plant, dairy, or egg grading centre; (3) food scientist or research officer at FIIRO, IITA, or a university animal science department working on improving processing technology and product quality; (4) cold chain and logistics manager for a distribution company handling chilled or frozen animal products; (5) entrepreneur establishing and managing a small or medium-scale animal products processing enterprise (abattoir, dairy processing unit, smoked fish business, hide and skin processing unit).
4. Primary processing: the first transformation of a live animal or raw product into a form suitable for further use; it involves major physical separation; example: slaughter and dressing of a cow into beef cuts, offal, hide, blood, and bones — the live animal is converted into multiple distinct primary products at this stage. Secondary processing: the further transformation of a primary product into a value-added product through additional operations; example: manufacturing beef sausages from fresh beef trim by grinding, mixing with seasonings and preservatives, stuffing into casings, and cooking or smoking — the primary product (beef) is converted into a differentiated consumer product with higher unit value.
5. Animal products technology draws on multiple scientific fields because the processes it manages are inherently multidisciplinary. Microbiology: the primary cause of animal product spoilage and foodborne disease is microbial; understanding bacterial growth kinetics, pathogen control, and fermentation requires microbiology. Biochemistry: rigor mortis, fat oxidation, protein denaturation, enzyme activity, and Maillard browning are all biochemical processes that determine product quality and shelf life. Food science and chemistry: formulation of processed products (sausages, cheese, dairy drinks) requires understanding of ingredient functionality, emulsification, texturisation, and preservation chemistry. Engineering: designing processing equipment, cold stores, abattoir drainage systems, and pasteurisers is an engineering discipline. Economics: understanding market values, processing costs, and return on investment is essential for commercial viability.

Part 1.2

1. Three traditional methods: (1) Kilishi (sun-drying combined with spicing): the preservation principle is moisture removal (water activity reduction below 0.85 prevents most bacterial growth); the groundnut paste coating creates a protective barrier and the spices (ginger, pepper, cloves) contribute antimicrobial essential oils; the combination of desiccation and antimicrobial compounds produces a shelf-stable product at ambient temperature in a hot, dry climate. (2) Suya (smoke-grilling): preservation principle is a combination of heat (destroys surface pathogens), desiccation (partial moisture removal), and antimicrobial compounds from wood smoke (phenols, aldehydes, and organic acids in smoke inhibit bacterial growth); suya is not shelf-stable (sold and consumed immediately) but the grill heat renders it microbiologically safe at point of sale. (3) Smoked fish: preservation principle is smoke compounds (antimicrobial phenols from wood smoke), desiccation (moisture removal during smoking reduces water activity), and heat; heavily smoked and well-dried fish can be shelf-stable for weeks at ambient temperature; light smoking requires refrigeration for extended storage.
2. Three major milestones: (1) Nicolas Appert's invention of heat sterilisation in sealed glass containers (1809; later adapted to metal cans by Durand, 1810): for the first time, food could be preserved indefinitely without requiring salt, smoke, or drying; this enabled long-distance transport of meat and dairy products and was critical for feeding armies and sailors; the commercial canning industry that followed transformed global food supply chains. (2) The invention and commercialisation of mechanical refrigeration (Carl von Linde, 1873): for the first time, temperature could be reduced below ambient in a controlled and sustained way without ice; refrigerated railway wagons and ships enabled the first international trade in chilled and frozen meat (Argentine and Australian beef to Britain from 1880s); within 50 years, refrigeration had transformed the entire global meat and dairy distribution system. (3) Louis Pasteur's demonstration of microbial spoilage and the germ theory of disease (1850s-1870s) and the application of controlled heating (pasteurisation) to destroy pathogens in milk (standardised by 1864): this provided the first scientific explanation for why food spoils, enabling rational design of preservation and processing systems based on controlling microbial growth rather than empirical tradition.
3. Louis Pasteur's significance: before Pasteur, the cause of food spoilage was unknown; various theories (spontaneous generation, chemical corruption) were held; processors could observe that

certain treatments prevented spoilage but had no scientific explanation for why. Pasteur's work demonstrated that fermentation and putrefaction are caused by specific microorganisms (not by spontaneous generation or chemical processes), that heating to specific temperatures destroys these microorganisms (pasteurisation), and that contamination from the environment introduces them. This understanding was revolutionary for animal products technology because: (1) it provided a scientific basis for designing pasteurisation conditions for milk; (2) it explained why certain traditional preservation methods (heating, drying, salting, smoking) worked; (3) it established the principle that controlling microbial growth — through temperature, water activity, pH, and barrier packaging — is the fundamental strategy of food preservation; (4) it led directly to the germ theory of disease which eventually generated food safety legislation, abattoir inspection systems, and veterinary public health programmes.

4. Pre-colonial: well-established processing traditions across ecological zones; kilishi and dambun nama (dried meats) in the north; nono (fermented milk) and wara (soft cheese) in cattle-keeping Middle Belt and north; smoked, dried, and fermented fish along the Niger River, Atlantic coast, and Niger Delta; these products met local nutritional and preservation needs and were traded regionally. Colonial era (early 20th century): British colonial administration introduced rudimentary abattoir infrastructure in major cities (Kano, Kaduna, Lagos) for public health control; refrigeration technology arrived for export of hides and skins rather than for domestic food processing; canning and import of European processed animal products grew. Post-independence (1960s-1980s): federal and state government investment in formal abattoirs; government dairy processing plants using exotic cattle; fisheries processing facilities; some formal meat canning. SAP disruption (1986): currency devaluation raised cost of imported equipment, spare parts, and ingredients; government subsidies were removed; many formal processing operations became uneconomic and collapsed. Post-1990s private sector recovery: integrated private companies emerged in poultry processing (Chi Farms, Zartech), dairy (FanMilk, Hollandia/CHI, Promasidor), and fish processing; artisanal sector continued; formal sector still small relative to the scale of animal product consumption.
5. Mechanical refrigeration changed animal products marketing and distribution in five fundamental ways: (1) Eliminated the season: before refrigeration, fresh meat and milk could only be safely consumed within a few hours of production in warm climates; refrigeration allowed milk collected in the morning to be safely consumed 5 to 7 days later, and fresh meat to be stored for 10 to 21 days; this eliminated the daily slaughter requirement and enabled centralised processing and bulk distribution. (2) Enabled global trade in fresh and chilled products: refrigerated ships (reefer ships) allowed Argentina and Australia to export chilled beef to Britain from the 1880s;

this created the first truly global meat market and drove the development of large-scale livestock industries in the Southern Hemisphere specifically for export; prices fell, availability increased, and consumer access to animal protein improved dramatically. (3) Enabled centralised slaughter and processing: before refrigeration, animals had to be slaughtered near the point of consumption; refrigeration allowed centralised large-scale abattoirs distant from retail markets to slaughter, process, and distribute carcasses across a city or country; this enabled economies of scale in processing and improved hygiene control. (4) Transformed dairy distribution: pasteurisation combined with refrigeration allowed milk to be transported from rural collection areas to urban processing plants and then to urban retail; this separated dairy production from urban consumption and created the modern milk supply chain. (5) Enabled cold chain for value-added products: refrigeration and freezing enable manufacturers to produce and distribute sausages, cheese, yoghurt, and other perishable processed products across large geographic areas with acceptable shelf lives.

Part 1.3

1. Four contributions to human nutrition: (1) Complete protein supply: animal products (meat, milk, eggs) provide all nine essential amino acids in proportions that closely match human requirements; plant proteins are generally deficient in one or more essential amino acids (limiting amino acids); the biological value of egg protein is 100 (the international reference standard), beef 80, and milk 91, compared with 65-75 for legumes; for Nigerians who are protein-deficient, animal products provide the most efficient route to meeting protein requirements. (2) Haem iron bioavailability: iron-deficiency anaemia affects 68% of Nigerian women of reproductive age; haem iron in red meat is absorbed at 15-35% efficiency, compared with 2-8% for non-haem iron in plants; even small quantities of red meat in the diet dramatically improve iron status; processed meat products (sausages, canned corned beef) extend meat availability beyond fresh slaughter and therefore contribute to iron nutrition. (3) Bioavailable minerals: dairy products are the most concentrated and bioavailable source of calcium; calcium from milk is absorbed at 30-35% efficiency compared with 5-10% from spinach and other high-oxalate plant sources; bone development and osteoporosis prevention depend critically on adequate calcium intake, making dairy products particularly important for children and pregnant women. (4) Fat-soluble vitamins: animal products are primary dietary sources of vitamins A (retinol in liver, eggs, full-fat dairy), D

(oily fish, eggs, dairy), and K2 (dairy, eggs); these vitamins are essential for immune function, bone metabolism, and eye health respectively.

2. Processing technology improves food security through temporal extension, spatial extension, and waste reduction. Temporal extension: processing converts perishable products with a shelf life of hours (fresh milk) or days (fresh meat) into storable commodities lasting months or years; pasteurised milk lasts 5-7 days refrigerated; UHT milk lasts 6-12 months at ambient temperature; dried milk powder lasts 12-24 months; this allows seasonal production surpluses to be stored and consumed during lean seasons when production is low (in Nigeria, Fulani cattle produce more milk in the wet season when grass is abundant; without processing, this surplus is lost when demand in the dry season is high). Spatial extension: processed products can be transported to distant markets that fresh products cannot reach due to spoilage; smoked catfish can travel from the Niger Delta to Kano (1,500 km) by road with a shelf life of weeks at ambient temperature; refrigerated processing extends this to chilled or frozen products reaching even more distant markets. Waste reduction: post-harvest losses of animal products in Nigeria are estimated at 20-40% for meat and up to 60% for fresh milk in the absence of processing and cold chain; processing dramatically reduces these losses, increasing the proportion of nutritional value from production that reaches the consumer.
3. Three ways the processing sector generates economic value: (1) Direct employment and wages: Nigeria's animal product processing sector (formal and informal combined) employs an estimated 500,000 to 1 million workers directly; this includes abattoir workers, butchers, dairy processing technicians, fish smokers, egg graders, sausage makers, and cold chain drivers; each worker earns a wage or income that supports household consumption and local economic activity; in the informal sector (the large majority), processing provides livelihoods for millions of rural and peri-urban households who have no alternative income source of equivalent scale. (2) Foreign exchange earnings: processed hides and skins (particularly Sokoto Red Goat leather, internationally known as Moroccan leather or Maradi leather) are among Nigeria's oldest and most consistent agricultural exports; finished, dyed, and graded goatskins command USD 3-8 per skin in European fashion leather markets; at 75 million goats nationally, even a small proportion entering the export leather market represents significant foreign exchange; dried crayfish, smoked fish, and palm oil derivatives are also exported regionally to West African markets, generating foreign exchange income. (3) Import substitution value: Nigeria imports dairy products worth over USD 1 billion per year (primarily UHT milk, powdered milk, cheese, and dairy-based beverages); every dollar's worth of domestic dairy processing that replaces an import saves foreign exchange and stimulates domestic upstream economic activity (feed production,

veterinary services, dairy farm investment); the National Dairy Policy targets a 40% reduction in import dependence through domestic processing investment.

4. Value addition is the increase in the economic market price of an animal product achieved through processing, packaging, branding, or quality certification beyond the unprocessed commodity price. Calculation of processing premium for raw milk in Nigeria: Farm-gate raw milk price: approximately NGN 200 to 400 per litre (paid to a Fulani producer by a dairy collector in Kaduna or Kano). Pasteurised packaged milk in a supermarket: approximately NGN 700 to 1,200 per litre equivalent in branded carton format. Processing premium: the difference is approximately NGN 300 to 800 per litre, representing a premium of 75 to 300 per cent above the farm-gate raw milk price. This premium covers processing costs (pasteurisation, packaging, cold chain, labour, overheads, distribution) and processor profit margin. The very existence of this premium signals to dairy farmers that quality raw milk delivered hygienically to a processing plant is worth more than milk sold to an informal roadside trader; it incentivises investment in improved dairy hygiene, milking hygiene, and on-farm cooling to meet processor specifications.
5. Hides and skins processing is economically important for northern Nigeria for several reasons: (1) Scale of raw material supply: Nigeria's cattle, sheep, and goat populations (approximately 20 million cattle, 40 million sheep, 75 million goats) are concentrated primarily in the north; each slaughtered animal yields one hide or skin; the northern abattoir sector (Kano, Sokoto, Maiduguri, Kaduna) processes millions of hides and skins annually; even low-value raw hides generate income for abattoir operators and collectors. (2) International premium for Sokoto Red leather: the Red Sokoto goat produces a thin, smooth, tightly grained skin that, after vegetable tanning and dyeing in the traditional Kano Kurmi market tanneries, becomes the internationally recognised Moroccan leather or Maradi leather; European fashion houses pay premium prices (USD 5-12 per finished skin) for authentic Kano-processed goatskin for use in gloves, shoes, handbags, and wallets; this creates a high-value export supply chain directly from northern Nigerian smallholder farmers to European fashion markets. (3) Employment in the leather industry: the Kano leather tanning industry employs thousands of traditional tanners (majiya) whose skills have been passed down for centuries; the industry supports auxiliary services including dye supply, hide transport, salt supply, and leather trading; modernisation of the tanning sector (chrome tanning, mechanised processes) would greatly expand export capacity and employment.

Part 1.4

1. Rigor mortis is the stiffening of muscles that occurs after the death of an animal, caused by the biochemical depletion of adenosine triphosphate (ATP) in muscle tissue. In living muscle, ATP drives the dissociation of the actin-myosin cross-bridges that form during muscle contraction; when new ATP is synthesised by mitochondrial oxidative phosphorylation (which requires oxygen), the cross-bridges break and the muscle relaxes. After slaughter, oxygen delivery to muscle ceases; the mitochondria rapidly exhaust available oxygen and switch to anaerobic glycolysis; glycolysis produces only 2 ATP per glucose molecule (vs 36 in aerobic respiration) and cannot keep pace with ATP consumption; as ATP concentration falls below the threshold required to break cross-bridges, actin and myosin permanently lock together and the muscle stiffens. The onset of rigor: in cattle 12-24 hours post-slaughter at 1-4 degrees Celsius; in pork 4-8 hours; in poultry 2-4 hours; faster at warmer temperatures. Resolution of rigor (conditioning or ageing): over 7-14 days (beef) or 1-3 days (pork) at 1-4 degrees Celsius, endogenous proteolytic enzymes (primarily calpain-1 and calpain-2, activated as calcium is released from damaged sarcoplasmic reticulum) cleave specific myofibrillar proteins (troponin T, nebulin, titin, desmin); this disrupts the structural integrity of the sarcomere and allows myofilaments to slide apart; the meat becomes progressively more tender as conditioning proceeds.
2. Post-harvest physiological changes in fresh milk: (1) Microbial contamination and multiplication: immediately after secretion from the udder, milk is exposed to environmental bacteria from the skin of the udder, the milking hands or equipment, the air, and the collection vessel; even from a hygienically managed milking, fresh milk typically contains 1,000 to 10,000 bacteria per mL; above 4 degrees Celsius, bacterial populations double every 20-30 minutes; at Nigerian ambient temperatures of 28-35 degrees Celsius, milk collected at 07:00 may have bacterial counts exceeding 10 million per mL by 11:00 — well above the safety threshold for consumption; the primary bacteria are mesophilic Gram-positive lactic acid bacteria (Lactobacillus, Streptococcus) and psychrotrophic Gram-negative bacteria (Pseudomonas, Acinetobacter) from the environment. (2) Acidification and coagulation: lactic acid bacteria ferment lactose (milk sugar) to lactic acid; the pH of fresh milk falls from 6.6-6.8 (fresh) toward 5.0-4.6 (clotted sour milk); at pH 4.6 (the isoelectric point of casein), the major milk protein casein coagulates and the milk curdles; this is the basis of traditional fermented products (nono, wara, yoghurt) and explains why unrefrigerated milk sours rapidly in Nigerian conditions. Significance for processing: fresh milk must be chilled to below 4 degrees Celsius within 2 hours of milking to prevent rapid bacterial multiplication; for commercial pasteurisation, milk delivered to the plant must meet an incoming plate count

standard (typically below 100,000 cfu/mL for Grade A raw milk) to ensure that pasteurisation produces a microbiologically safe product; milk with very high incoming bacterial loads may still fail safety standards even after pasteurisation if heat-stable bacterial toxins (e.g. Staphylococcus aureus toxins) have been produced before heating.

3. Three main causes of deterioration and storage controls: (1) Microbial growth: bacteria, moulds, and yeasts colonise animal products and produce enzymes that break down proteins (putrefaction, sliminess), fats (rancidity), and carbohydrates (sour off-flavours); they also produce toxins that cause foodborne illness. Storage control: temperature reduction (refrigeration to 0-4 degrees Celsius slows growth; freezing to -18 degrees Celsius arrests it; pasteurisation kills most vegetative cells before storage); water activity control (drying or salting reduces available moisture, preventing microbial growth at aw below 0.85 for most bacteria). (2) Enzymatic activity: endogenous enzymes in muscle tissue continue to act post-mortem; lipases break down fat triglycerides releasing free fatty acids (rancidity); proteases tenderise meat during conditioning but over-tenderise in prolonged storage; lysozyme in eggs has limited antibacterial activity. Storage control: refrigeration slows enzymatic reaction rates; freezing nearly arrests enzyme activity; blanching (brief heat treatment) denatures enzymes before freezing or drying; pH control (the acidic pH of conditioned meat inhibits some enzymes). (3) Chemical reactions: lipid oxidation (rancidity) occurs when unsaturated fatty acids react with oxygen, producing off-flavours and odours; Maillard browning occurs when amino acids react with reducing sugars during heating or prolonged storage at elevated temperature; haem oxidation converts oxymyoglobin (bright red) to metmyoglobin (brown) in meat exposed to oxygen. Storage control: modified atmosphere packaging (high CO_2, low O_2 or vacuum) prevents lipid oxidation and haem oxidation; antioxidants (vitamin E, butylated hydroxytoluene BHT) in feed or in processing retard lipid oxidation; temperature reduction slows the rate of all chemical reactions.
4. NAFDAC (National Agency for Food and Drug Administration and Control) role: NAFDAC requires registration and safety certification of all commercially processed food products in Nigeria before they can be legally manufactured, imported, exported, advertised, distributed, or sold; manufacturers must submit product formulation, processing method, packaging, and food safety testing data for NAFDAC review; NAFDAC inspectors conduct plant inspections to verify that Good Manufacturing Practice (GMP) standards are met; only products carrying a valid NAFDAC registration number on the label can be legally sold in Nigerian markets; violation results in product seizure, plant closure, fines, and prosecution. SON (Standards Organisation of Nigeria) role: SON develops Nigerian Industrial Standards (NIS) for specific animal products; examples include NIS 52 for raw cow's milk, NIS 53 for pasteurised milk, NIS for eggs, and NIS

for fresh meat; these standards specify permissible bacterial limits, physical and chemical composition requirements (minimum fat content, minimum protein content), and labelling requirements; SON inspectors may sample products from retail shelves and test against the NIS; products failing to meet NIS standards may be withdrawn from sale; SON Certification Mark indicates conformance with the relevant standard and provides quality assurance to buyers.

5. HACCP (Hazard Analysis and Critical Control Points) is a systematic preventive food safety management approach that identifies biological (bacterial pathogens), chemical (pesticide residues, veterinary drug residues), and physical (bone fragments, metal shards) hazards at each step of the animal product processing chain and establishes specific control measures at the Critical Control Points (CCPs) where those hazards can most effectively be controlled. The seven HACCP principles are: (1) conduct a hazard analysis; (2) identify CCPs; (3) establish critical limits; (4) establish monitoring procedures; (5) establish corrective actions; (6) establish record-keeping and documentation; (7) verify the system. Why HACCP is required for formal market access: NAFDAC requires HACCP plans from processors applying for product registration; major Nigerian supermarket chains (Shoprite, Spar, Game) require their animal product suppliers to have HACCP-based quality assurance systems; export health certificates (required for exporting Nigerian animal products to EU, USA, and Middle East markets) require demonstration of HACCP compliance; institutional buyers (hospitals, schools, hotels, military) increasingly require food safety certification from their suppliers; without HACCP, Nigerian animal product processors cannot access these higher-value, higher-volume formal markets, limiting their ability to grow beyond the informal sector.

References and Attributions [Series 1]

Textual References (Books and External Sources)

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

Figures, Plates, Tables, and Boxes

- Figure 1.1: Traditional Nigerian animal product processing photographs Attribution: AI generated. Suggested OER search string: "traditional Nigerian animal products kilishi suya wara smoked fish processing OER photograph".
- Figure 1.2: Animal products value chain economic value addition diagram Attribution: AI generated. Suggested OER search string: "animal products value chain economic value addition processing Nigeria OER diagram".
- Box 1.1: Post-harvest physiological changes in major animal products summary Attribution: AI generated. Suggested OER search string: "post-harvest physiology animal products rigor mortis milk spoilage egg quality OER box".

Course code: AGE 408

Course title: Animal Products Handling, Processing and Storage

Course credit load: 2 Units

Series 2: Slaughtering Techniques, Carcass Care, and Meat Processing

- **Part 2.1: Pre-Slaughter Handling and Slaughtering Techniques**
  - Sub Part 2.1.1: Pre-slaughter handling and lairage
  - Sub Part 2.1.2: Slaughtering methods and stunning
  - Sub Part 2.1.3: Halal slaughter and religious requirements
- **Part 2.2: Dressing, Evisceration, and Carcass Inspection**
  - Sub Part 2.2.1: Dressing procedures for cattle, sheep, and pigs
  - Sub Part 2.2.2: Evisceration and offal recovery
  - Sub Part 2.2.3: Dressing percentage and carcass classification
- **Part 2.3: Carcass Care, Chilling, and Cutting**
  - Sub Part 2.3.1: Post-slaughter carcass care
  - Sub Part 2.3.2: Chilling and cold chain management
  - Sub Part 2.3.3: Carcass cutting and meat types
- **Part 2.4: Hides, Skins, and Meat Processing**
  - Sub Part 2.4.1: Processing and care of hides and skins
  - Sub Part 2.4.2: Meat processing: curing, smoking, and sausage manufacture
  - Sub Part 2.4.3: Effect of cooking on meat quality and flavour

Introduction

The slaughter and processing of animals for meat is a technically demanding chain of operations where errors at any stage reduce product safety, quality, and value. Pre-slaughter stress, improper stunning, poor hygiene during dressing and evisceration, or inadequate chilling can render an otherwise healthy carcass unsafe or commercially unacceptable. This Series covers the complete slaughter-to-retail meat processing sequence.

Topics covered include pre-slaughter handling and lairage, slaughtering and stunning methods, halal requirements, dressing procedures, evisceration, carcass inspection and classification, post-slaughter care, chilling, cutting and meat types, hide and skin processing, meat curing and smoking, sausage manufacture, and the effect of cooking on meat quality and flavour.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** describe the principles of pre-slaughter handling and lairage and explain how stress affects meat quality (Linked to Part 2.1),
- **SLO 2.2** describe the major slaughtering and stunning methods and explain the requirements of halal slaughter (Linked to Part 2.1),
- **SLO 2.3** describe the dressing and evisceration procedures for cattle, sheep, and pigs and define dressing percentage (Linked to Part 2.2),
- **SLO 2.4** describe carcass inspection and classification systems (Linked to Part 2.2),
- **SLO 2.5** describe post-slaughter carcass care and explain the importance of the cold chain (Linked to Part 2.3),
- **SLO 2.6** identify major meat cuts and describe the meat types from different species (Linked to Part 2.3),
- **SLO 2.7** describe the processing and care of hides and skins (Linked to Part 2.4), and
- **SLO 2.8** describe meat curing, smoking, sausage manufacture, and the effects of cooking on meat quality (Linked to Part 2.4).

2.1 Pre-Slaughter Handling and Slaughtering Techniques

2.1.1 Pre-slaughter handling and lairage

Pre-slaughter handling encompasses all activities from when animals leave the farm until they are stunned. Poor pre-slaughter management is the leading cause of meat quality defects and economic loss in Nigerian abattoirs. Key principles: avoid mixing unfamiliar animals (fighting causes bruising and stress); avoid feed for 12 to 24 hours before slaughter (reduces gut fill and rumen contamination during evisceration) but maintain water access; transport animals in the cool of the morning or evening to minimise heat stress.

Lairage is the holding facility at the abattoir where animals rest before slaughter. A good lairage provides: shade and water; adequate space (minimum 1.5 to 2.0 m2 per cattle, 0.5 m2 per sheep or goat); separation of species; drainage; and a calm, low-stress environment. Animals should rest for a minimum of 24 hours in the lairage to allow muscles to replenish glycogen reserves depleted during transport stress; glycogen depletion leads to DFD (dark, firm, dry) meat in cattle.

Fill in the blank: Animals should rest in the lairage for a minimum of ________ hours before slaughter to replenish muscle glycogen reserves; failure to do so leads to DFD (dark, firm, dry) meat with reduced shelf life and consumer rejection.

2.1.2 Slaughtering methods and stunning

Humane stunning renders the animal unconscious before bleeding, reducing stress and improving meat quality by preventing a massive catecholamine surge at the moment of death. Methods: electrical stunning (passing an electric current through the brain via electrodes applied to the temples; standard for pigs and small ruminants; 250-350 V for 1-3 seconds in cattle, 70-90 V for pigs); captive bolt stunning (a pneumatic or cartridge-powered steel rod penetrates the skull and destroys the brain; standard for cattle; kills or deeply stuns).

Carbon dioxide (CO_2) gas stunning: animals exposed to high-concentration CO_2 (70-90%) lose consciousness; used in large pig abattoirs; the animal does not struggle and bruising is minimal. Bleeding (exsanguination): the carotid arteries and jugular veins are severed; cattle are bled in approximately 3 to 5 minutes (4 to 6 litres of blood recovered); inadequate or delayed bleeding results in blood retention in the carcass, reducing quality and shelf life. For halal slaughter, the animal must be conscious at the time of bleeding (see Sub Part 2.1.3).

Fill in the blank: Captive bolt stunning is standard for cattle; a pneumatic or cartridge-powered steel rod destroys the ________ to render the animal deeply unconscious or killed before bleeding.

2.1.3 Halal slaughter and religious requirements

Halal meat processing is a legal and commercial requirement for the majority of the Nigerian market. Islamic law (Sharia) requires: the animal must be alive and healthy at the time of slaughter; the slaughterman must be a Muslim; the name of Allah must be recited (Bismillah, Allahu Akbar) at the time of slaughter; the animal's throat must be cut with a single swift stroke of a sharp blade, severing the trachea, oesophagus, carotid arteries, and jugular veins; the animal must be bled completely; pork is prohibited.

Pre-slaughter stunning is disputed in Islamic jurisprudence. A significant proportion of Nigerian Islamic scholars (particularly in the north where the major cattle abattoirs are located) permit electrical or captive bolt stunning only if the animal is confirmed alive after stunning and before bleeding. Reversible stunning methods (electrical head-only stunning, which leaves the animal recoverable if not bled) are generally accepted; irreversible stunning (penetrating captive bolt directly into the brain, causing death) is rejected by many authorities. Nigerian meat processors must balance welfare requirements with customer expectations in a predominantly Muslim market.

Fill in the blank: For halal slaughter, the ________ must be alive at the time of cutting and must be bled completely; the name of Allah must be recited at the moment of slaughter.

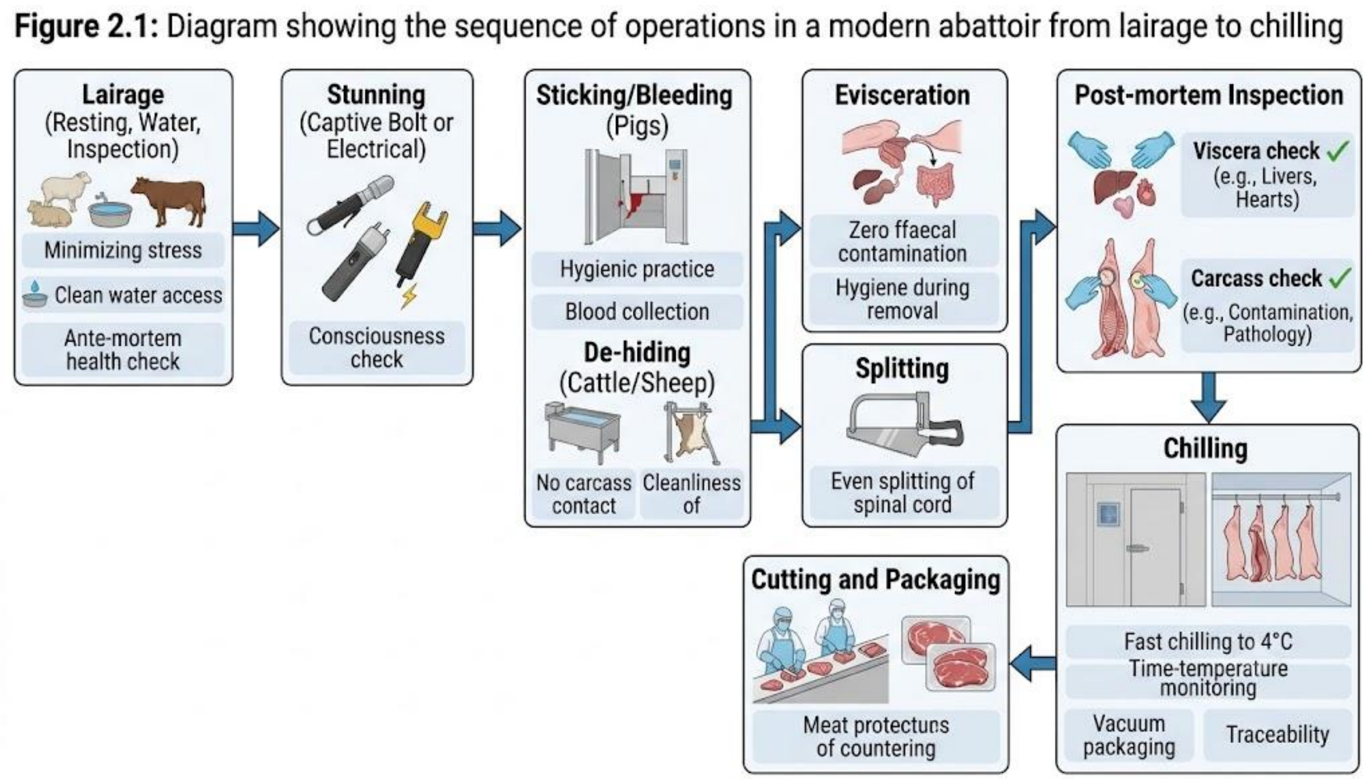

Figure 2.1: Diagram showing the sequence of operations in a modern abattoir from lairage to chilling

Pilot questions 2.1

1. Explain why animals should be rested in the lairage before slaughter and describe ideal lairage conditions.
2. Describe three methods of pre-slaughter stunning and state when each is used.
3. Explain why inadequate bleeding is a meat quality problem.
4. State the key requirements for halal slaughter of cattle in Nigeria.
5. Explain the controversy around pre-slaughter stunning in the context of halal requirements.

2.2 Dressing, Evisceration, and Carcass Inspection

2.2.1 Dressing procedures for cattle, sheep, and pigs

Dressing is the conversion of a slaughtered animal into a carcass suitable for further processing or retail. For cattle: the carcass is hoisted by the hind legs on a rail; the skin is removed (flaying) starting at the legs and belly; the head is removed at the atlanto-occipital joint and submitted for inspection; the feet are removed at the knee and hock joints; the tail is removed; the pubic symphysis is split; and the carcass is split into two sides (bilateral halves) along the vertebral column using a saw.

For sheep and goats: the carcass is hoisted; skin removed similarly but more quickly (smaller carcass; more delicate skin); the carcass is usually not split but presented as a whole carcass. For pigs: pigs are either skinned (similar to cattle) or scalded and scraped (immersed in hot water at 62 to 65 degrees Celsius for 3 to 5 minutes to loosen hair, then scraped clean); the scalded pig is then opened and eviscerated; pigs may be split or left as whole carcasses depending on the market.

Fill in the blank: Pigs can be processed by skinning (removing the hide) or by ________ (immersion in hot water at 62-65 degrees Celsius for 3-5 minutes to loosen hair for scraping), depending on market and carcass weight.

2.2.2 Evisceration and offal recovery

Evisceration is the removal of the internal organs from the carcass cavity. The correct sequence prevents contamination: the bung (rectum) is tied off before opening the abdominal cavity to prevent faecal contamination; the abdominal cavity is opened along the midline; the gastrointestinal tract (stomach, intestines), liver, spleen, and pancreas are removed in one unit (the gut set); the thoracic cavity is then opened and the heart, lungs (pluck), and trachea removed. Each organ must be kept associated with its carcass for inspection.

Edible offal (organ meats) recovered for human consumption: liver, kidneys, heart, tongue, tripe (rumen/stomach), lungs (used in pet food or some markets), and tail. Inedible offal: intestinal contents, bile, gall bladder, hooves. Blood is collected in containers for processing into blood meal (animal feed) or blood sausage. In Nigerian abattoirs, offal is highly valued; liver, kidneys, and tripe (roundabout) are sold fresh at premium prices. Offal must be cleaned, chilled, and separately handled to prevent cross-contamination of carcass meat.

Fill in the blank: The ________ (rectum) must be tied off before opening the abdominal cavity during evisceration to prevent faecal contamination of the carcass interior.

2.2.3 Dressing percentage and carcass classification

Dressing percentage (DP) is the ratio of carcass weight to live weight: DP = (carcass weight / live weight) x 100. Typical values: cattle 52 to 60%; sheep 45 to 55%; pigs 70 to 80% (higher because the skin is often retained in pig processing and gut fill is less). Factors affecting DP: breed (well-muscled breeds have higher DP); nutrition (well-fed animals have more muscle and fat); gut fill (animals not fasted may have 3 to 5% lower DP); sex (bulls slightly higher DP than cows); and age (older animals generally have higher DP than young animals at equivalent body weight).

Carcass classification systems assess carcass commercial value. Nigerian informal markets largely trade on live weight and subjective assessment. Formal classification systems (based on the EU SEUROP system adapted for Nigeria) assess: conformation (overall muscling and shape: S=superior, E=excellent, U=good, R=average, O=fair, P=poor); fat cover (a score 1 to 5, where 1 is lean and 5 is very fat); and weight class. A well-conformed, adequately fat carcass commands a premium; poorly conformed or excessively fat carcasses are discounted.

Fill in the blank: Dressing percentage = (carcass weight / ________ weight) x 100; typical values are 52-60% for cattle, 45-55% for sheep, and 70-80% for pigs.

Species	**Typical Dressing Percentage**	**Factors Affecting Dressing %**
Cattle	52–60%	Breed (Bos indicus zebu 52–56%; improved beef breeds 58–62%), nutrition (well-fed animals higher DP), gut fill (12-hour fast raises DP by 2–3%), sex (bulls slightly higher than cows)

Sheep	45–55%	Wool weight (shorn sheep have 2–3% higher DP)
Pigs	70–80%	Higher because skin retained in scalded processing; affected by backfat thickness and breed
Poultry	72–76% (broilers)	Influenced by age, nutrition, and processing method (see Series AGE 406 Series 4)

Box 2.1: Typical dressing percentages and factors affecting them by species

Pilot questions 2.2

1. Describe the dressing procedure for cattle, listing the steps in the correct order.
2. Explain why the bung must be tied before evisceration and what happens if it is not.
3. Name six edible offal products recovered from cattle at slaughter.
4. Define dressing percentage and calculate it for a 450 kg bull that yields a 252 kg carcass.
5. Explain the basis of carcass classification and state the criteria used.

2.3 Carcass Care, Chilling, and Cutting

2.3.1 Post-slaughter carcass care

Immediately after evisceration and inspection, the carcass must be washed with potable water to remove blood clots, hair, and contamination; the wash water should be at ambient or cold temperature (not hot, which would promote surface bacterial growth). The carcass cavity is sprayed with an approved organic acid solution (lactic acid 2 to 5%, or acetic acid) to reduce surface bacterial contamination; this acid wash decontamination can reduce Salmonella and E. coli counts by 1 to 2 log10.

Carcass identification: each carcass is tagged with a unique identifier linking it to the live animal ante-mortem inspection record and the post-mortem inspection findings. Any condemned parts are removed and the remaining carcass stamped as "passed for human consumption" by the meat inspector. The carcass is then transferred to the chiller as quickly as possible; the time from slaughter to chill room entry should not exceed 45 minutes in a well-managed abattoir, and 90 minutes is the maximum acceptable in typical Nigerian conditions.

Fill in the blank: Carcasses are sprayed with ________ acid (2-5%) or acetic acid after washing to reduce surface bacterial contamination by 1 to 2 log10 before entering the chiller.

2.3.2 Chilling and cold chain management

Rapid chilling is the single most important post-slaughter intervention for meat quality and safety. Chilling targets: beef carcass surface temperature below 7 degrees Celsius within 24 hours of slaughter (EU and Codex standard); internal temperature (deep leg) below 7 degrees Celsius within 24 to 30 hours; sheep and goats within 12 to 16 hours; pigs within 12 hours. Carcass chillers operate at 0 to 4 degrees Celsius with high air velocity (1 to 3 m/s) to rapidly extract heat.

Cold shortening must be avoided: if beef or lamb carcasses are chilled too rapidly before rigor is complete, the muscle contracts excessively and permanent toughness results (cold shortening); this is prevented by chilling beef carcasses to no lower than 10 degrees Celsius within the first 10 hours. Cold chain: once chilled, meat must remain at 0 to 4 degrees Celsius throughout distribution; every break in the cold chain (a warm delivery vehicle, an unrefrigerated market stall) accelerates bacterial growth. In Nigeria, cold chain failure is the leading cause of premature meat spoilage beyond the abattoir.

Fill in the blank: Cold ________ occurs when beef or lamb carcasses are chilled too rapidly before rigor is complete; the muscle contracts excessively and the meat becomes permanently tough even after conditioning.

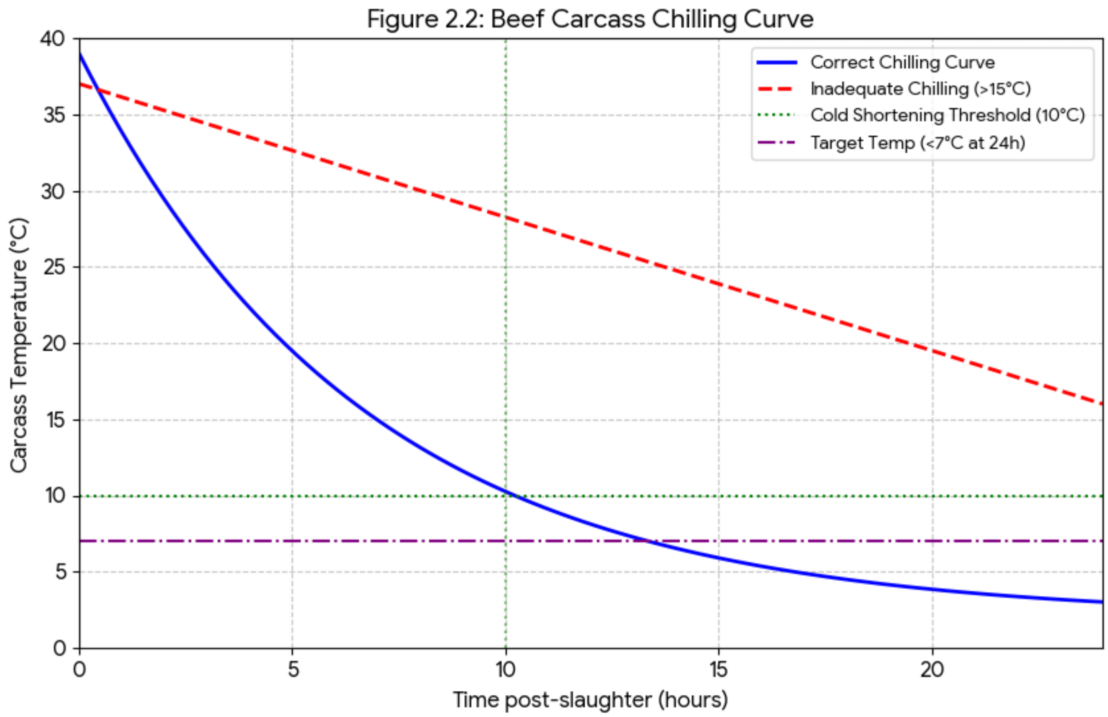

Figure 2.2: Diagram of a standard beef chilling curve showing correct carcass temperature decline over 24 hours

2.3.3 Carcass cutting and meat types

Beef is cut into primary (wholesale) cuts that are further divided into secondary (retail) cuts. Standard Nigerian abattoir beef cuts from a side of beef: forequarter (chuck, brisket, rib, plate, shank — front leg); hindquarter (round, flank, loin, sirloin, rump — back half). The hindquarter cuts are more valuable (more tender, more lean). Offcuts and trim are used for mince (ground beef) or processed products (sausages, burgers). Bone-in cuts are standard in Nigerian retail; boneless cuts are growing in formal retail and food service.

Meat types by species: beef (red meat; high myoglobin; strong flavour; variable tenderness by cut); mutton (mature sheep; stronger flavour than lamb; tougher); lamb (young sheep; pale, tender, mild); chevon (goat; slightly lean, distinctive mild flavour; very popular in Nigeria); pork (light-coloured red meat; high fat content; loin and belly most popular); poultry meat (white muscle of breast versus dark of leg; lighter flavour; most tender of all meats when fresh). Meat colour is determined primarily by myoglobin content: poultry breast has very little; beef is richest in myoglobin.

Fill in the blank: Meat colour is determined primarily by ________ content; beef is richest in myoglobin (dark red), while poultry breast muscle contains very little myoglobin (pale white).

Pilot questions 2.3

1. Explain why rapid transfer from slaughter to the chiller is important.
2. Describe cold shortening: what causes it, when it occurs, and how it is prevented.
3. Name five primary beef cuts and state which half of the carcass each comes from.
4. Explain why hindquarter cuts are more valuable than forequarter cuts.
5. Compare meat types from cattle, sheep, goats, and poultry in terms of colour, tenderness, and flavour.

2.4 Hides, Skins, and Meat Processing

2.4.1 Processing and care of hides and skins

A hide (from cattle or horse) or skin (from sheep, goat, pig, or small animal) is recovered at slaughter and is the single most valuable by-product of the slaughter operation after the carcass. Immediate care: the hide must be removed cleanly without knife cuts (scores) that reduce leather quality; it must be salted within 1 to 2 hours of removal to prevent bacterial putrefaction; dry salt (approximately 30 to 40% of hide weight) is spread evenly on the flesh side; hides are then stacked flesh-to-flesh and left to cure for 24 to 48 hours before transport.

Tanning converts the raw hide into leather, a stable non-putrescible material. Two main tanning methods: vegetable tanning (using plant-derived tannins from bark; produces firm, brown leather used for sole leather, saddles, and belts; traditional Kano tanneries use this method) and chrome tanning (using chromium sulphate salts; produces soft, flexible leather in 8 to 24 hours versus weeks for vegetable tanning; used for uppers, garments, and gloves; the dominant modern industrial method). Wet blue is the intermediate product after chrome tanning, before finishing and dyeing.

Fill in the blank: Fresh hides must be salted within ________ to 2 hours of removal from the carcass to prevent bacterial putrefaction; approximately 30 to 40 per cent of hide weight in dry salt is applied to the flesh side.

Figure 2.3: Photograph of the traditional Kano tannery showing vegetable tanning pits and workers processing hides

Figure 2.3: Photograph of the traditional Kano tannery showing vegetable tanning pits and workers processing hides

2.4.2 Meat processing: curing, smoking, and sausage manufacture

Curing is the preservation of meat using salt (sodium chloride), nitrite (sodium or potassium nitrite), and often sugar and spices. Salt lowers water activity, inhibiting microbial growth. Nitrite (100 to 150 ppm permitted in most countries) has three functions: inhibits Clostridium botulinum (the most dangerous food pathogen in cured meats); reacts with myoglobin to form the stable pink nitrosomyoglobin colour of cured meats; and has antioxidant activity. Curing methods: dry curing (rubbing salt-nitrite mixture onto the meat surface); brine curing (immersing in a salt-nitrite-water solution); injection curing (pumping brine directly into the muscle).

Smoking: exposing cured or uncured meat to wood smoke (hardwoods such as oak, hickory, or fruitwood; in Nigeria, various hardwoods are used for kilishi, suya, and smoked fish). Smoke compounds (phenols, carbonyls, organic acids) contribute antimicrobial activity, antioxidant activity, and characteristic flavour and colour. Hot smoking (60 to 80 degrees Celsius) both cooks and preserves; cold smoking (below 30 degrees Celsius) primarily flavours without fully cooking. Sausage manufacture: meat trim and fat are ground, mixed with salt, nitrite, spices, and non-meat ingredients (starch, water, soy protein), stuffed into natural (intestine) or artificial casings, and then cooked, smoked, or dried depending on type.

Fill in the blank: Nitrite in cured meats inhibits ________ botulinum, forms the stable pink colour of cured meat, and has antioxidant activity; the permitted level is 100 to 150 ppm in most countries.

2.4.3 Effect of cooking on meat and meat flavour

Cooking irreversibly transforms the physical and chemical structure of meat. Protein denaturation: heat above 40 degrees Celsius begins to denature myosin; above 70 degrees Celsius most proteins are denatured; denaturation increases water expulsion (cooking loss) and toughens the texture. Collagen conversion: connective tissue collagen converts to gelatin above 70 to 80 degrees Celsius with prolonged moist heat cooking; this is why tougher collagen-rich cuts (e.g. brisket, shank) become tender when braised or boiled for extended periods but remain tough when quickly grilled.

Flavour development: the characteristic aroma and taste of cooked meat arise primarily from Maillard reaction (between amino acids and reducing sugars at meat surface temperatures above 120 degrees Celsius during roasting, grilling, or frying) and from thermal degradation of lipids, producing volatile compounds. Fat from the specific diet of the animal contributes to species-characteristic flavour (grain-fed beef has different flavour volatiles than pasture-fed). Water-soluble compounds (nucleotides, amino acids, peptides) contribute to the basic meaty taste (umami). Overcooking destroys these flavour compounds and produces harsh, burnt notes.

Fill in the blank: The characteristic brown colour and aroma of grilled or roasted meat arise from the ________ reaction between amino acids and reducing sugars at surface temperatures above 120 degrees Celsius.

Method	**Process**	**Preservative Effects**
Curing	Salt + nitrite application	Lowers water activity; inhibits *Clostridium botulinum*; forms stable pink colour; antioxidant; extends shelf life to weeks
Hot Smoking	60–80 °C; smoke exposure	Cooks and preserves; antimicrobial phenols from smoke; reduces moisture; extends shelf life
Cold Smoking	<30 °C; smoke exposure	Adds flavour; limited preservation without drying/cooking; requires refrigeration for safety
Sausage Manufacture	Combination of salt, nitrite, smoke, heat	Multiple preservation barriers; formulated texture and flavour; extended shelf life
Drying/Jerky (Kilishi)	Severe moisture reduction	High reduction in water activity; shelf-stable at ambient temperature

Box 2.2: Summary of meat processing methods and their preservative effects

Pilot questions 2.4

1. Explain why hides must be salted within 2 hours of removal and describe the salting process.
2. Distinguish between vegetable tanning and chrome tanning.
3. Explain the three functions of nitrite in cured meat products.
4. Distinguish between hot smoking and cold smoking in terms of temperature, effect, and preservation.
5. Explain how collagen conversion during cooking affects the tenderness of different meat cuts.

Series Summary

This Series covered the complete slaughter-to-retail meat processing chain. Pre-slaughter: lairage rest (minimum 24 hours) replenishes glycogen; DFD meat results from chronic stress; feed withdrawal 12-24 hours reduces gut contamination. Stunning (captive bolt for cattle; electrical for pigs and small ruminants; CO_2 for large pig plants) reduces stress and improves quality. Halal requires a live, healthy animal, Muslim slaughterman, recitation of Allah's name, and complete bleeding. Reversible stunning is generally accepted by Nigerian Islamic scholars.

Dressing: cattle are flayed, eviscerated, and split; sheep presented whole; pigs skinned or scalded-scraped. DP = carcass weight / live weight x 100 (cattle 52-60%; sheep 45-55%; pigs 70-80%). Post-mortem inspection, acid wash, and rapid chilling (to <7 degrees Celsius within 24 hours, avoiding cold shortening below 10 degrees Celsius in the first 10 hours) are critical. Meat cuts from forequarter (lower value) and hindquarter (higher value). Hides salted within 1-2 hours; tanned by vegetable (Kano traditional) or chrome (modern) methods. Curing (salt + nitrite), smoking (hot or cold), and sausage manufacture extend shelf life. Cooking causes protein denaturation, collagen-gelatin conversion, and Maillard flavour development. By completing this Series, you should achieve all eight SLOs (2.1 to 2.8).

Glossary of Terms

- **Brine curing:** immersion of meat in a salt-nitrite-water solution to achieve preservation; used for ham, bacon, and corned beef.
- **Bung:** the rectum of a slaughter animal; must be tied off before evisceration to prevent faecal contamination of the carcass.
- **Captive bolt:** a pneumatic or cartridge-powered stunning device that drives a steel rod into the brain to render an animal unconscious or dead before bleeding; standard for cattle.
- **Chrome tanning:** a rapid (8-24 hours) tanning method using chromium sulphate; produces soft, flexible leather; the dominant modern industrial method.

- **Cold chain:** the unbroken series of refrigerated storage and transport steps that maintains chilled or frozen meat from slaughter to consumer.
- **Cold shortening:** excessive muscle contraction causing permanent toughness when beef or lamb carcasses are chilled below 10 degrees Celsius before rigor mortis is complete.
- **Curing:** preservation of meat using salt, nitrite, and often sugar and spices; extends shelf life and creates characteristic flavour and pink colour.
- **DFD (dark, firm, dry) meat:** meat with a high ultimate pH (>6.2) due to glycogen depletion before slaughter; dark in colour, firm texture, reduced shelf life.
- **Dressing:** the conversion of a slaughtered carcass into a form suitable for further processing or retail; includes skinning/scalding, evisceration, splitting, and trimming.
- **Dressing percentage (DP):** carcass weight as a percentage of live weight; typical values: cattle 52-60%; sheep 45-55%; pigs 70-80%.
- **Edible offal:** organ meats suitable for human consumption; includes liver, kidneys, heart, tongue, and tripe; highly valued in Nigerian markets.
- **Evisceration:** removal of internal organs (gut set and pluck) from the carcass cavity during dressing; carried out hygienically with the bung tied.
- **Flaying:** the process of removing the skin (hide) from a carcass by cutting and pulling; requires skill to avoid knife scores that reduce leather quality.
- **Halal:** meat and food prepared in accordance with Islamic law; requires a live animal, Muslim slaughterman, recitation of Allah's name, and complete exsanguination.
- **Hot smoking:** exposing meat to wood smoke at 60-80 degrees Celsius; both cooks and preserves; antimicrobial phenols and desiccation extend shelf life.
- **Lairage:** the holding facility at the abattoir where animals rest, are watered, and are observed before slaughter.
- **Maillard reaction:** a chemical reaction between amino acids and reducing sugars during heating above 120 degrees Celsius; produces brown colour and characteristic cooked meat aroma.
- **Myoglobin:** the oxygen-binding muscle pigment responsible for meat colour; beef is richest (red); poultry breast has least (pale white).

- **Nitrite:** a preservative in cured meats (sodium or potassium nitrite; 100-150 ppm); inhibits Clostridium botulinum, forms pink colour, and is an antioxidant.
- **Pluck:** the heart, lungs, and trachea removed as a unit during evisceration; the lungs are used for pet food or in some human food markets.
- **Scalding:** immersion of a pig carcass in hot water (62-65 degrees Celsius for 3-5 minutes) to loosen hair for scraping; an alternative to skinning.
- **Vegetable tanning:** a traditional, slow (weeks) tanning method using plant-derived tannins from bark; produces firm leather for soles, saddles, and belts; used in Kano tanneries.
- **Wet blue:** the intermediate product of chrome tanning (a blue-grey pliable hide) before finishing and dyeing into final leather.

Concept Check Questions [Series 2]

Objective Questions

1. Animals should rest in the lairage for a minimum of ________ hours before slaughter to replenish muscle glycogen and prevent DFD meat. (Linked to SLO 2.1)
2. Captive bolt stunning is standard for cattle; it destroys the ________ to render the animal unconscious or dead before bleeding. (Linked to SLO 2.2)
3. Dressing percentage = carcass weight / ________ weight x 100; typical values are 52-60% for cattle and 70-80% for pigs. (Linked to SLO 2.3)
4. Cold ________ occurs when beef carcasses are chilled below 10 degrees Celsius before rigor is complete, causing permanent muscle toughness. (Linked to SLO 2.5)
5. The ________ reaction between amino acids and reducing sugars above 120 degrees Celsius produces the brown colour and aroma of grilled or roasted meat. (Linked to SLO 2.8)

Short-Answer Questions

1. State the key requirements for halal slaughter. (Linked to SLO 2.2)
2. Explain why the bung must be tied before evisceration. (Linked to SLO 2.3)
3. Define cold shortening and explain how it is prevented. (Linked to SLO 2.5)

4. State the three functions of nitrite in cured meat products. (Linked to SLO 2.8)
5. Distinguish between vegetable tanning and chrome tanning. (Linked to SLO 2.7)

Long-Answer Questions

1. Describe the principles of pre-slaughter handling and lairage, slaughtering and stunning methods, and the requirements of halal slaughter. (Linked to SLOs 2.1, 2.2)
2. Describe the dressing and evisceration procedures for cattle, define dressing percentage, and explain post-slaughter carcass care and chilling. (Linked to SLOs 2.3, 2.4, 2.5)
3. Describe the processing of hides and skins, explain meat curing and smoking, and describe the effects of cooking on meat quality and flavour. (Linked to SLOs 2.7, 2.8)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. 24.
2. Brain.
3. Live.
4. Shortening.
5. Maillard.

Short-Answer Questions

1. Animal must be alive and healthy at time of slaughter; slaughterman must be Muslim; name of Allah must be recited; throat cut in a single stroke severing trachea, oesophagus, carotid arteries, and jugular veins; animal must be completely bled; pork is prohibited.
2. The bung (rectum) contains faecal material; if it is not tied before opening the abdominal cavity, faeces will spill onto the carcass interior during evisceration, contaminating the meat with enteric pathogens (Salmonella, E. coli, Campylobacter) and causing carcass downgrade or condemnation.
3. Cold shortening is excessive, permanent muscle contraction and toughening that occurs when beef or lamb carcasses are chilled below 10 degrees Celsius before rigor mortis is complete. Prevention: maintain carcass temperature above 10 degrees Celsius for the first 10 hours post-

slaughter by controlling chiller air temperature and airflow; electrical stimulation of the carcass can also accelerate rigor completion, allowing faster subsequent chilling.

(1) Inhibits Clostridium botulinum (the most dangerous pathogen in cured meats; produces a heat-stable neurotoxin); (2) reacts with myoglobin to form stable pink nitrosomyoglobin (the characteristic colour of cured meats such as ham and bacon); (3) antioxidant activity (retards rancidity in the fat fraction of cured products).

4. Vegetable tanning: uses plant-derived tannins from bark; slow process (weeks to months); produces firm, brown leather for soles, saddles, and belts; traditional method used in Kano tanneries; not waterproof. Chrome tanning: uses chromium sulphate salts; rapid (8-24 hours); produces soft, flexible leather for garments, gloves, and shoe uppers; dominant modern method; produces wet blue intermediate.

Long-Answer Questions

1. Pre-slaughter handling: avoid mixing unfamiliar animals (bruising and stress); withhold feed 12-24 hours (reduces gut fill, rumen contamination risk); maintain water access; transport in cool periods. Lairage: shade, water, 1.5-2.0 m2/cattle, 0.5 m2/small ruminant; 24-hour minimum rest to replenish glycogen (prevents DFD meat). Stunning methods: captive bolt (cattle; penetrating rod destroys brain); electrical (250-350 V 1-3 sec cattle; 70-90 V pigs; small ruminants); CO2 gas (70-90%; large pig plants; minimal bruising). Bleeding: sever carotid arteries and jugular veins; 3-5 minutes; 4-6 litres blood per cattle; inadequate bleeding causes blood retention and reduced quality. Halal: animal alive and healthy; Muslim slaughterman; Bismillah Allahu Akbar recited; single swift cut severing trachea, oesophagus, carotid arteries, jugular veins; complete bleeding; no pork. Stunning controversy: reversible (head-only electrical) generally accepted by Nigerian Islamic scholars; irreversible (penetrating captive bolt causing death) rejected by many authorities.
2. Cattle dressing: hoist by hind legs; flay hide (starting at legs and belly); remove head at atlanto-occipital joint (submitted for inspection separately); remove feet at knee and hock; remove tail; split pubic symphysis; split carcass along vertebral column into two sides. Sheep: hoist, flay, present as whole unsplit carcass. Pigs: skin or scald-scrape (62-65 degrees Celsius, 3-5 min). Evisceration: tie bung before opening abdomen; open along midline; remove gut set (stomach, intestines, liver, spleen) as one unit; open thorax; remove pluck (heart, lungs, trachea); keep organs with carcass for inspection. Edible offal: liver, kidneys, heart, tongue, tripe. DP = carcass weight / live weight x 100; cattle 52-60%; sheep 45-55%; pigs 70-80%; factors: breed, nutrition, gut fill, sex, age. Post-slaughter care: wash carcass

with potable water; spray with lactic acid 2-5% (decontamination: 1-2 log10 reduction in Salmonella and E. coli); tag for traceability; inspector stamps as "passed for human consumption"; transfer to chiller within 45-90 minutes. Chilling: 0-4 degrees Celsius; high air velocity; surface temperature below 7 degrees Celsius within 24 hours (beef); avoid chilling below 10 degrees Celsius in first 10 hours (cold shortening risk). Cold shortening: muscle contacts excessively before rigor complete; permanent toughness; prevented by holding above 10 degrees Celsius for first 10 hours or by electrical stimulation of carcass.

3. Hides and skins: hide recovered at slaughter (most valuable by-product after carcass); must be removed without knife scores; salted within 1-2 hours of removal (30-40% hide weight dry salt, flesh side); stacked flesh-to-flesh, cure 24-48 hours; transport to tannery. Tanning: vegetable tanning (plant tannins; weeks; firm brown leather; Kano tradition; soles, saddles, belts) vs chrome tanning (chromium sulphate; 8-24 hours; soft flexible leather; dominant industrial method; garments, gloves; produces wet blue intermediate). Curing: salt (lowers water activity) + nitrite (100-150 ppm; inhibits C. botulinum; pink colour; antioxidant) + sugar and spices; methods: dry cure, brine cure, injection cure. Smoking: hot smoking (60-80 degrees Celsius; cooks and preserves; antimicrobial phenols, carbonyls; desiccation; kilishi, suya, smoked fish) vs cold smoking (<30 degrees Celsius; flavour only; requires refrigeration). Sausage manufacture: grind meat trim and fat; mix with salt, nitrite, spices, non-meat ingredients (starch, water, soy protein); stuff natural or artificial casings; cook/smoke/dry. Cooking effects: protein denaturation (above 40 degrees Celsius myosin; above 70 degrees Celsius most proteins; cooking loss increases; texture firms); collagen-to-gelatin conversion (above 70-80 degrees Celsius with moist heat; tough cuts (brisket, shank) become tender after prolonged braising/boiling); flavour development (Maillard reaction above 120 degrees Celsius on surface; amino acids + reducing sugars; brown colour and roasted aroma; lipid thermal degradation; species-characteristic volatile compounds; umami from water-soluble nucleotides and amino acids).

Answers to Pilot Questions [Series 2]

Part 2.1

1. Animals need lairage rest for two critical reasons: (1) glycogen replenishment (transport, mixing, and handling deplete muscle glycogen through stress-induced catecholamine release

and muscle activity; without adequate glycogen in muscle at slaughter, post-mortem lactic acid production is insufficient to lower pH to the normal ultimate pH of 5.4-5.8; the muscle pH remains abnormally high at 6.2 or above, producing DFD (dark, firm, dry) meat which is darker in colour, stickier, has reduced shelf life due to higher pH allowing faster bacterial growth, and commands a lower market price); (2) physiological recovery from handling stress (stress causes elevated blood cortisol, adrenaline, and heart rate; these hormones alter muscle metabolism and can cause PSE (pale, soft, exudative) in pigs; 24 hours of calm lairage rest allows hormone levels to return to baseline). Ideal lairage conditions: covered shelter from sun and rain; continuous access to clean water (withheld from feed 12-24 hours before slaughter); minimum space 1.5-2.0 m2 per head of cattle, 0.5 m2 per sheep or goat; separation of species (cattle and pigs stress each other); good drainage; low-stress handling (avoiding electric goads, shouting, or sudden movements); quiet ambient environment.

2. Three stunning methods: (1) Captive bolt stunning: a pneumatic or cartridge-powered device drives a solid (non-penetrating: mushroom-headed) or penetrating (hollow-headed) steel bolt into the skull with sufficient force to cause concussion (non-penetrating) or brain destruction (penetrating); penetrating captive bolt is standard for cattle in large abattoirs; the animal is instantaneously rendered deeply unconscious or killed; must be followed immediately by bleeding while the heart is still beating to ensure complete exsanguination; used for cattle, pigs, and (occasionally) large sheep. (2) Electrical stunning: an electric current is passed through the animal's brain via electrodes applied to the temples (head-only) or through the body (head-to-body); the current induces a tonic-clonic epileptic-like seizure and unconsciousness; 250-350 V for 1-3 seconds in cattle; 70-90 V at 50 Hz for pigs; used for pigs, sheep, and cattle; head-only electrical stunning is reversible and is therefore the most widely accepted form among Islamic scholars for halal processing. (3) CO_2 gas stunning: pigs are moved into a pit or gondola filled with 70-90% CO_2 gas; they lose consciousness within 30-45 seconds; the animal does not struggle, minimising bruising and physical injury; used in large industrial pig processing plants; not suitable for ruminants (ruminants inhale gas slowly through their forestomach; CO_2 can cause ruminal tympany before unconsciousness).
3. Inadequate bleeding is a meat quality problem for three reasons: (1) Blood retention in the carcass: blood is the primary growth medium for bacteria in the carcass; retained blood in tissues, large blood vessels, and haematomas (blood pools from bruising) provides nutrients for rapid bacterial multiplication; this accelerates spoilage and reduces shelf life beyond what is expected from the surface contamination alone. (2) Appearance: consumers associate dark red blood-stained areas in the carcass or in meat cuts with poor hygiene and freshness; blood

retained around injection or puncture sites causes dark, blood-soaked patches that reduce consumer appeal and commercial value. (3) Haemolytic flavour: blood has a characteristic metallic haemolytic flavour; when retained in muscle tissue, this contributes an off-flavour to the cooked meat particularly around the neck, chest, and major blood vessel regions. (4) In halal slaughter specifically, incomplete bleeding is a validity issue: Islamic law requires complete exsanguination as part of the halal process; if blood is retained, the product may not be accepted as fully halal-compliant by some authorities.

4. Key requirements for halal slaughter of cattle in Nigeria: (1) The animal must be alive and in good health at the time the slaughter cut is made; animals that are already dead from disease, injury, or prior stunning that kills rather than stuns cannot be used for halal meat. (2) The slaughterman must be a Muslim adult who is competent in the slaughter procedure; non-Muslim slaughtermen cannot perform halal slaughter even if all other conditions are met. (3) The name of Allah must be individually invoked at the time of each slaughter cut: "Bismillah, Allahu Akbar" (In the name of God, God is the Greatest); this invocation cannot be recorded and played from a loudspeaker but must be recited by the slaughterman for each animal. (4) The slaughter instrument must be a sharp blade (knife, not an axe or blunt instrument) that is free from nicks; a single swift cut must sever the trachea (windpipe), oesophagus (gullet), both carotid arteries, and both jugular veins; the spinal cord must not be severed before the animal is fully bled. (5) The animal must be completely bled (full exsanguination); the blood must drain freely and completely from the carcass; retained blood renders the product impermissible. (6) Pork and pork-derived products are strictly prohibited for Muslim consumers regardless of slaughter method.
5. The controversy: Islamic jurisprudence (fiqh) scholars differ on whether pre-slaughter stunning is compatible with halal requirements because the core debate is whether stunning kills the animal or merely renders it unconscious. The Quran explicitly requires that the animal be alive (with a heartbeat and functioning blood circulation) when the slaughter cut is made; if the stunning method kills the animal before the cut, the meat is not halal. The debate therefore focuses on: (1) reversible vs irreversible stunning: reversible head-only electrical stunning (the animal would recover consciousness and normal physiological function within minutes if not bled) is accepted by most Nigerian Islamic scholars and by the Malaysian and most Middle Eastern halal certification authorities; the animal is considered alive when cut because it would recover; irreversible methods (penetrating captive bolt that destroys the brain; controlled atmosphere killing where the animal dies from the gas before cutting) are rejected by the majority of traditional Islamic scholars because the animal is dead before the

cut. (2) Practical commercial pressure: the Nigerian formal meat processing sector deals with large throughputs where unstunned animals are dangerous to slaughter workers (a frightened cattle in a traditional Muslim abattoir can injure or kill workers); animal welfare organisations pressure processors to use stunning; large export markets (European) require pre-stun by law; the tension between traditional jurisprudence and commercial/welfare reality is ongoing and resolved differently by different Nigerian states and slaughter facilities.

Part 2.2

1. Correct sequence of cattle dressing: (1) The bled carcass is hoisted by the hind legs onto an overhead rail system; (2) The head is removed at the atlanto-occipital joint (the articulation between the skull and the first cervical vertebra); the head is retained for post-mortem inspection (lymph nodes and masseter muscles are examined for tuberculosis and cysticercosis); (3) The forefeet are removed at the knee (carpus) joints; (4) The hide is opened along the midline of the belly and legs (a "running cut"); (5) Flaying proceeds: the hide is separated from the carcass by a combination of cutting (knife) and pulling (fisting, a technique using the fist to push between hide and fat without cutting scores); (6) The hindfeet are removed at the hock (tarsus) joints; (7) The tail is removed at its base; (8) The sternum (breastbone) is split with a saw or cleaver; (9) The pubic symphysis (the junction of the pelvic bones) is split to allow the hind legs to separate; (10) The abdomen is opened (bung already tied) and the viscera removed (see evisceration sequence); (11) The carcass is split into two bilateral halves using a saw along the vertebral column from the pelvis to the neck; (12) The carcass halves are washed, inspected, and transferred to the chiller.
2. During evisceration, the large intestine (colon) and rectum contain a large volume of semi-solid faecal material (in cattle, typically 10-20 litres of rumen and intestinal contents in total); if the bung (rectal opening) is not ligated (tied) with a string or sealed in a plastic bag before the abdominal cavity is opened, faeces will spill directly onto the carcass interior surfaces (the peritoneal lining, the loin muscles, and other exposed meat surfaces) as the intestines are manipulated during removal; faeces in cattle contain high concentrations of Escherichia coli (including the pathogenic O157:H7 strain), Salmonella species, Campylobacter, Listeria monocytogenes, and numerous other bacteria; even a small faecal contamination event can deposit millions of bacteria per square centimetre onto meat surfaces; this contamination cannot be removed by subsequent washing and requires the affected surfaces to be trimmed

away (reducing yield) or, if extensive, results in condemnation of the entire carcass; in a commercial abattoir, one evisceration hygiene failure can contaminate the carcass, the inspection equipment, the workers' gloves, and the overhead rail, creating a risk of cross-contamination for subsequent carcasses.

3. Six edible offal products: (1) Liver: the largest solid organ; contains high concentrations of vitamin A, vitamin B12, haem iron, and folate; in Nigeria, beef liver is sold fresh at abattoir gate at premium prices to restaurants and households; it must be chilled rapidly and consumed within 24-48 hours; (2) Kidneys: paired bean-shaped organs; strong characteristic flavour due to urea content (must be soaked before cooking); sold fresh; less popular in Nigeria than liver but widely consumed; (3) Heart: dense cardiac muscle; rich in myoglobin and coenzyme Q10; sliced and grilled or used in stews; considered a delicacy; (4) Tongue: a large muscular organ; very tender when braised due to high collagen content that converts to gelatin; in Nigeria, beef tongue is sold both in urban markets and at abattoir gates; (5) Tripe (roundabout or shaki in Yoruba): the rumen and reticulum of cattle and sometimes the omasum; sold cleaned and washed (white tripe) or partially cooked at markets; used in pepper soups, stews, and as a street food; highly popular throughout Nigeria; (6) Intestines (cleaned and prepared): small intestines of cattle and sheep are cleaned thoroughly, boiled, and sold as a street food ingredient or in stews in some Nigerian markets.
4. Dressing percentage definition: DP (%) = (hot carcass weight / live body weight) x 100; it represents what proportion of the live animal is recovered as a saleable carcass after removal of the blood, skin, head, feet, and all viscera (with giblets and offal separately valued). Calculation for a 450 kg bull yielding a 252 kg carcass: DP = (252 / 450) x 100 = 56 per cent. This is within the normal range for Nigerian Bos indicus zebu cattle (52-56%) and indicates good nutrition, adequate slaughter weight, and correct fasting and dressing procedure; if the DP had been below 50%, it would suggest that the animal was poorly nourished, heavily pregnant (retained foetus weight), or that there was excessive trim loss during dressing from knife scores or contamination; if DP were above 60%, it might suggest the animal was a well-conditioned improved beef breed or that the live weight was inaccurately recorded.
5. Carcass classification is a systematic, objective method of describing and grading the commercial value of a slaughtered carcass based on measurable physical characteristics that predict consumer value. The basis: producers want to be paid according to the quality (muscle, fat, and total saleable meat content) of the carcass they deliver to an abattoir; buyers (retailers, processors) want to predict how much saleable retail meat a carcass will yield and at what quality; without a classification system, both sides must rely on subjective

negotiation; a standardised classification system provides a transparent, market-wide pricing mechanism. The criteria used in formal carcass classification systems (based on the EU SEUROP system adapted for Africa): (1) Conformation: the overall shape, compactness, and muscle development of the carcass evaluated visually or objectively; scored S (superior, very full convex profiles; seen in specialised beef breeds), E (excellent), U (good), R (average; typical of most Nigerian Bos indicus carcasses), O (fair), or P (poor; very angular carcass); a higher conformation grade predicts a higher proportion of saleable retail meat per kg of carcass weight. (2) Fat cover: the degree of external fat (subcutaneous fat) covering the carcass assessed by feel and visual inspection; scored 1 (very lean) to 5 (very fat); an appropriate fat cover (score 2-3 for most markets) predicts good marbling, eating quality, and acceptable waste from fat trimming; very lean carcasses (score 1) risk desiccation in the chiller; very fat carcasses (score 4-5) have excessive trim waste. (3) Weight class: the hot carcass weight in kilograms is recorded and the carcass classified into weight bands; weight class affects processing suitability and market compatibility.

Part 2.3

1. Rapid transfer from slaughter to the chiller is important for two reasons: (1) Microbial safety: meat surface temperatures between 10 and 37 degrees Celsius are optimal for the rapid multiplication of the bacterial contamination acquired during slaughter (Salmonella, Campylobacter, E. coli, Staphylococcus aureus, Pseudomonas); at 25 degrees Celsius (a typical Nigerian ambient temperature), bacterial populations can double every 20-30 minutes; the longer the carcass remains at ambient temperature before entering the chiller, the higher the initial bacterial load that the cold chain must then manage; starting the cold chain with a high bacterial load means the carcass will reach its microbiological shelf-life limit much earlier; (2) Meat quality: several enzyme-driven processes (lipase activity, haem oxidation, proteolysis) proceed faster at ambient temperature than at chiller temperatures; each hour at ambient temperature before chilling represents a measurable loss of colour stability, fat quality, and texture; in Nigeria, where abattoir-to-market distribution often involves warm transport vehicles or unrefrigerated market conditions, this initial period of chilling delay is critically important because it determines the total quality and safety budget available for the distribution chain.

2. Cold shortening is a meat quality defect specific to beef and lamb (not pork or poultry) that occurs when the muscle temperature falls below 10 degrees Celsius while the muscle still has sufficient ATP and calcium ion concentration to support active contraction but before the onset of rigor mortis (the exhaustion of ATP). The mechanism: after slaughter, ATP is still present in the muscle (rigor is not yet complete); as temperature falls, the calcium pump in the sarcoplasmic reticulum becomes inefficient and calcium ions accumulate in the sarcoplasm; at temperatures below 10 degrees Celsius, the myosin ATPase enzyme activity remains high enough to form new actomyosin cross-bridges; since the actin and myosin are still mobile (ATP is still present), the muscle can actively contract; this contraction shortens the sarcomere length well below the optimum for overlap between actin and myosin; when ATP is eventually exhausted, rigor sets in at this abnormally shortened sarcomere length; the shortened sarcomeres are permanently locked in the contracted state because the subsequent proteolytic tenderisation (conditioning) cannot return them to optimal length. Prevention: maintain the deep carcass temperature above 10 degrees Celsius for the first 10 hours after slaughter by controlling the chiller temperature and airflow to achieve rapid surface cooling without over-cooling the deep muscle; alternatively, electrical stimulation of the carcass (applying electric current to the carcass immediately after slaughter) rapidly depletes ATP and accelerates rigor completion, allowing the carcass to be chilled to below 10 degrees Celsius immediately without cold shortening risk.
3. Five primary beef cuts and their carcass location: (1) Chuck (forequarter): the neck and shoulder region; includes muscles of the neck and forelimb that are heavily exercised and therefore tough; used for stewing, braising, or mince. (2) Rib (forequarter): the 6th to 12th ribs and their associated muscle; the longissimus dorsi muscle begins here; includes prime rib; used for slow roasting. (3) Loin (hindquarter): the short loin from the 13th rib to the hip bone; the most tender section of the longissimus dorsi; sirloin and T-bone steaks come from here; very high value; lowest collagen content. (4) Round (hindquarter): the large muscle mass of the hind leg; relatively lean but moderately tough (used muscles); used for roasting, braising, or slicing for stir-fry. (5) Brisket (forequarter): the breast and lower chest muscles; very high collagen content; becomes very tender when braised or boiled for long periods; used for corned beef.
4. Hindquarter cuts are more valuable than forequarter cuts for three reasons: (1) Tenderness: the muscles of the hindquarter (loin, sirloin, rump, round) are less actively exercised during the life of the animal than the muscles of the forequarter (chuck, brisket, plate); less exercised muscles have less connective tissue (collagen) per unit weight and shorter, more regular

muscle fibres; this makes them naturally more tender when cooked at relatively moderate temperatures (grilling, pan-frying); the forequarter muscles, with their higher collagen content, require prolonged moist heat to convert collagen to gelatin before they become tender. (2) Fat distribution: the hindquarter (particularly the loin and rib-eye area) accumulates more intramuscular fat (marbling) than the forequarter in well-fed cattle; marbling fat (fat deposited between muscle fibre bundles) melts during cooking and lubricates the meat fibres, improving juiciness and perceived tenderness. (3) Lean meat yield: the hindquarter muscles are typically larger, more anatomically regular, and more easily separated from bone and connective tissue to yield clean lean meat portions; boneless hindquarter steak is a high-value retail product; boneless forequarter meat yields more connective tissue trim and less clean retail-cut weight per kg of bone-in carcass weight.

5. Comparison of meat types from four species: Cattle (beef): dark red colour due to high myoglobin content; variable tenderness from very tender (loin and rib cuts from young animals) to tough (chuck and brisket from older animals); strong characteristic beefy flavour from higher myoglobin, fat content, and species-specific volatile compounds (branched-chain fatty acids from rumen fermentation give beef its distinctive grassy, beefy character); long production cycle; most expensive per kg in Nigeria. Sheep/goat (mutton, lamb, chevon): mutton is darker red than lamb; distinct "gamey" flavour from branched-chain fatty acids (4-methyloctanoic acid and related compounds) in the fat; chevon (goat meat) has a milder and less fatty flavour than mutton and is widely preferred in Nigeria; young animals (lamb, kid) are pale and tender; older animals (mutton) are tougher and stronger-flavoured. Pigs (pork): intermediate colour (lighter red than beef; higher in the heme-myoglobin content than poultry but less than beef); high fat content particularly in the loin, belly, and jowl; a characteristic pork flavour from skatole and androstenone (from boar taint in entire males); very tender due to short muscle fibres and low collagen in loin cuts; susceptible to PSE (pale, soft, exudative) defect under stress. Poultry: breast muscle is pale (almost white) due to very low myoglobin content (fast-twitch fibres adapted for burst flight rather than sustained movement); leg and thigh are darker red due to higher myoglobin (slow-twitch endurance fibres for walking); very tender in the breast; more flavourful in the leg due to higher fat and myoglobin; distinctive mild poultry flavour from volatile sulphur compounds and lipid degradation products.

Part 2.4

1. Hides must be salted within 1-2 hours of removal for a critical reason: within minutes of being removed from the carcass, the warm, moist flesh surface (37 degrees Celsius; high protein content; neutral pH) becomes an ideal growth medium for environmental bacteria including putrefactive organisms (Bacillus, Pseudomonas, Micrococcus) and pathogenic species; these bacteria rapidly hydrolyse the collagen fibres of the dermis, causing a process called "slippage" (the epidermis separates from the dermis) and "putrefaction" (protein hydrolysis producing foul odours and discolouration); once putrefaction begins, the structural integrity of the leather is permanently compromised and tanning cannot produce quality leather; salt inhibits bacterial growth by lowering water activity (aw falls below 0.75 at 30-40% NaCl concentration, preventing virtually all bacterial activity). The salting process: the hide is laid flat, flesh side up, on a clean surface (cement floor or pallet); dry granular salt (30-40 % of the hide's weight in salt) is spread evenly over the entire flesh surface, paying special attention to the edges, leg folds, and neck region where putrefaction starts first; the hide is then folded or stacked flesh-to-flesh with another salted hide; the stack is left undisturbed for 24-48 hours to allow the salt to draw moisture from the hide tissues (osmotic dehydration) and equilibrate to the preservation concentration; the cured hide can then be safely transported to a tannery or stored for weeks.
2. Vegetable tanning and chrome tanning are the two dominant methods for converting raw animal hide into leather, and they differ in the tanning agent used, the process duration, the resulting leather properties, and their commercial applications. Vegetable tanning: the tanning agent is plant-derived tannins (polyphenolic compounds extracted from the bark, wood, or fruit of various trees including quebracho, chestnut, mimosa, and oak); the process is slow (days to weeks in traditional pit tanneries; 2-4 weeks is typical for heavy leather in Kano); the tannin molecules penetrate the collagen fibres gradually and form stable cross-links through hydrogen bonding and van der Waals forces; the resulting leather is firm, dense, and brown in colour; it has natural warmth and stiffness that makes it ideal for sole leather, saddlery, belts, and traditional craft leather goods; vegetable-tanned leather develops a characteristic patina with age and use; the Kano tanneries of northern Nigeria use this method with locally available tanning materials and produce leather that is exported to European fashion markets as "Moroccan leather"; the process requires large volumes of tanning liquor and generates significant wastewater. Chrome tanning: the tanning agent is basic chromium sulphate ($Cr(OH)SO_4$) which forms coordinate bonds with the carboxyl groups of collagen amino

acids; the process is very rapid (8-24 hours in a rotating drum); the resulting leather is pale blue-grey in colour (wet blue) with very high wet strength, softness, and flexibility; it can be dyed in virtually any colour and finished to any texture; it is the dominant method for garment leather, glove leather, shoe uppers, and automotive upholstery; chrome tanning generates chromium-containing wastewater (a significant environmental concern) which must be treated before discharge.

3. Nitrite performs three distinct and critical functions in cured meat products: (1) Inhibition of Clostridium botulinum: Clostridium botulinum is an anaerobic spore-forming bacterium that can grow in the oxygen-depleted, protein-rich, neutral-pH interior of cured meats (particularly in canned or vacuum-packed products) if they are not adequately heat-processed; C. botulinum produces botulinum neurotoxin, one of the most potent biological toxins known (the lethal dose in humans is a few nanograms per kilogram body weight); botulinum toxin is heat-labile (destroyed by normal cooking) but in ready-to-eat cured products that are consumed without further cooking (canned corned beef, vacuum-packed ham), the prevention of C. botulinum growth is critical; nitrite (at 100-150 ppm as sodium nitrite) in combination with salt, pH, and water activity effectively inhibits C. botulinum outgrowth from spores; removing nitrite from cured meats would significantly increase the risk of botulism from these products. (2) Formation of nitrosomyoglobin (pink colour): myoglobin in fresh meat is red (oxymyoglobin); when nitrite is added to meat in curing, nitric oxide (derived from nitrite) reacts with myoglobin to form nitrosomyoglobin (NOMb), which is a stable, bright pink compound; on cooking, NOMb denatures to form the characteristic stable pink nitrosohaemochromogen, the colour consumers associate with ham, bacon, corned beef, and sausages; without nitrite, cured meat would be a greyish-brown colour (as in uncured cooked meat), which is commercially unacceptable to most consumers. (3) Antioxidant activity: nitrite delays the oxidative rancidity of the fat fraction in cured meat products; fat oxidation produces off-flavours (rancid, painty, or warmed-over flavour) that shorten shelf life and reduce consumer acceptance; nitrite inhibits lipid oxidation by scavenging free radicals and chelating the iron ions in haem that catalyse lipid oxidation, extending the pleasant freshly-cured flavour during shelf life.

4. Hot smoking and cold smoking differ in five key dimensions: Temperature: hot smoking is carried out at internal smoke chamber temperatures of 60-80 degrees Celsius, sufficient to raise the internal product temperature to 65-72 degrees Celsius (fully cooking the product); cold smoking is carried out at temperatures below 30 degrees Celsius (typically 15-25 degrees Celsius) and the product is not cooked. Effect on the product: hot-smoked products

are fully cooked and shelf-stable at ambient temperature for limited periods or under refrigeration for extended periods; cold-smoked products retain a raw or cured texture similar to the fresh product and require refrigeration for safety since pathogenic bacteria have not been killed. Preservation mechanism: hot smoking achieves preservation through a combination of (a) heat destruction of vegetative bacterial cells and most pathogens, (b) moisture reduction (desiccation lowers water activity), and (c) deposition of antimicrobial smoke compounds (phenols, organic acids, carbonyls); cold smoking achieves preservation primarily through (a) smoke compound deposition and (b) moisture reduction (both to a lesser degree than hot smoking); cold-smoked products therefore have weaker preservation and require supplementary controls (salt curing before smoking, refrigeration after smoking). Examples: hot-smoked products in Nigeria include kilishi (heavily dried and smoked beef), smoked catfish and tilapia (traditional production), and suya (smoke-grilled to temperature); cold-smoked products include some traditional lightly smoked fish varieties that are salted before smoking and require quick consumption or refrigeration.

5. Collagen is the dominant structural protein of connective tissue in meat; it forms the tendons, intermuscular sheaths, and epimysium that link muscle fibres together and anchor muscles to bone; during the life of the animal, collagen is cross-linked (the older the animal, the more stable the cross-links) and gives toughness and chewiness to muscles that are heavily exercised and therefore rich in connective tissue. The effect of cooking on collagen: (1) at temperatures below 70 degrees Celsius, collagen swells and softens slightly but remains as solid collagen; the meat becomes more tender but collagen is still present; (2) when internal meat temperature exceeds 70-80 degrees Celsius with sufficient time (prolonged moist heat, as in braising, boiling, or slow cooking), the stable triple-helix structure of collagen is disrupted and it undergoes a phase transition, dissolving into gelatin; gelatin is a water-soluble protein with no structural integrity in the hot state, making the previously tough meat literally fall apart; as the cooking liquid cools, the dissolved gelatin forms a gel (e.g. meat jelly in the braising liquid). Practical implication for Nigerian cooks and processors: cuts from heavily exercised muscles with high collagen content (brisket, shank, chuck, oxtail, tripe) must be cooked by prolonged moist heat methods (boiling in pepper soup, slow-braising, pressure cooking) to achieve tenderness; the same cuts grilled or pan-fried quickly at high temperature will remain unpleasantly tough because the short cooking time is insufficient to convert collagen to gelatin; premium tender cuts from the loin and sirloin (low collagen content) are suited to quick high-heat cooking (grilling, frying) and are ruined by

prolonged boiling which causes excessive protein denaturation and moisture loss without the benefit of collagen-to-gelatin conversion that makes the tough cuts desirable.

References and Attributions [Series 2]

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Figures, Plates, Tables, and Boxes

- Figure 2.1: Abattoir operations sequence flow diagram Attribution: AI generated. Suggested OER search string: "abattoir operations sequence lairage stunning bleeding evisceration chilling diagram OER".
- Box 2.1: Dressing percentages by species and affecting factors Attribution: AI generated. Suggested OER search string: "dressing percentage cattle sheep pig poultry factors OER box".
- Figure 2.2: Beef carcass chilling curve graph Attribution: AI generated. Suggested OER search string: "beef carcass chilling curve cold shortening prevention temperature time graph OER".
- Figure 2.3: Kano tannery photograph Attribution: AI generated. Suggested OER search string: "Kano tannery leather hides skins vegetable tanning Nigeria photograph OER".
- Box 2.2: Meat processing methods and preservation effects summary Attribution: AI generated. Suggested OER search string: "meat processing methods curing smoking sausage drying preservation effects OER box".

Course code: AGE 408

Course title: Animal Products Handling, Processing and Storage

Course credit load: 2 Units

Series 3: Preservation, Storage, and Hygiene of Animal Products

- **Part 3.1: Principles and Methods of Preservation**
    - Sub Part 3.1.1: Causes of animal product spoilage
    - Sub Part 3.1.2: Physical methods of preservation
    - Sub Part 3.1.3: Chemical and biological methods of preservation
- **Part 3.2: Storage of Animal Products**
    - Sub Part 3.2.1: Refrigeration and freezing storage
    - Sub Part 3.2.2: Storage of meat, eggs, and milk
    - Sub Part 3.2.3: Storage losses and their control
- **Part 3.3: Hygiene in Animal Product Handling**
    - Sub Part 3.3.1: Personal hygiene of food handlers
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    - Sub Part 3.3.3: Good Manufacturing Practice
- **Part 3.4: Foodborne Illness and Safety**
    - Sub Part 3.4.1: Major foodborne pathogens from animal products
    - Sub Part 3.4.2: Prevention of foodborne illness
    - Sub Part 3.4.3: Food safety regulation in Nigeria

Introduction

Animal products deteriorate rapidly without intervention. Understanding why they spoil, what preservation methods slow or stop spoilage, and how storage conditions must be managed is central to reducing post-harvest losses and delivering safe food to consumers. Hygiene failures at any point in the chain can undo all preservation effort by reintroducing pathogens to treated products.

This Series covers the causes of spoilage, the major physical and chemical preservation methods, storage principles and losses, personal and facility hygiene, Good Manufacturing Practice, the key foodborne pathogens from animal products, and the food safety regulatory framework in Nigeria.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** identify the major causes of animal product spoilage and explain how each leads to deterioration (Linked to Part 3.1),
- **SLO 3.2** describe the physical methods of preservation and explain the principle behind each (Linked to Part 3.1),
- **SLO 3.3** describe the chemical and biological methods of preservation used for animal products (Linked to Part 3.1),
- **SLO 3.4** describe the principles of refrigeration and freezing storage and their application to meat, eggs, and milk (Linked to Part 3.2),
- **SLO 3.5** explain the causes and control of storage losses in animal products (Linked to Part 3.2),
- **SLO 3.6** describe personal hygiene requirements and facility hygiene standards for animal product handlers (Linked to Part 3.3),
- **SLO 3.7** describe Good Manufacturing Practice and identify the major foodborne pathogens associated with animal products (Linked to Parts 3.3 and 3.4), and
- **SLO 3.8** explain how foodborne illness is prevented and describe the food safety regulatory framework in Nigeria (Linked to Part 3.4).

3.1 Principles and Methods of Preservation

3.1.1 Causes of animal product spoilage

Spoilage of animal products results from three main causes. Microbial activity: bacteria, moulds, and yeasts colonise meat, milk, and eggs and produce enzymes that break down protein (putrefaction), fat (rancidity), and carbohydrates, generating off-odours, sliminess, and gas. Most spoilage bacteria are mesophiles (optimum 25 to 40 degrees Celsius) though psychrotrophic bacteria grow at 0 to 7 degrees Celsius in chillers.

Enzymatic activity: endogenous enzymes in muscle and milk continue to act after slaughter or secretion. Lipases break down fat; proteases break down protein; these reactions are desirable during meat conditioning but excessive activity causes off-flavours and texture loss. Chemical reactions: lipid oxidation (rancidity) and Maillard browning occur independently of microbial activity and are accelerated by heat, light, oxygen, and metals.

Fill in the blank: The three main causes of animal product spoilage are ________ activity, enzymatic activity, and chemical reactions such as lipid oxidation and Maillard browning.

3.1.2 Physical methods of preservation

Heat treatment: pasteurisation (63 degrees Celsius for 30 minutes or 72 degrees Celsius for 15 seconds for milk) destroys vegetative pathogens; sterilisation (121 degrees Celsius for 15 minutes under pressure) destroys spores and achieves commercial sterility for canned products; UHT (ultra-high temperature, 135 to 145 degrees Celsius for 2 to 6 seconds) gives shelf-stable liquid products.

Cold: refrigeration (0 to 4 degrees Celsius) slows but does not stop microbial growth; freezing (below minus 18 degrees Celsius) arrests growth and most enzymatic activity. Drying: reducing water activity (aw) below 0.85 prevents most bacterial growth; sun drying, mechanical drying, and spray drying are used for fish, meat, and milk powder. Irradiation: ionising radiation (gamma rays) destroys pathogens without raising temperature; approved for poultry and spices.

Fill in the blank: UHT processing at 135 to 145 degrees Celsius for 2 to 6 seconds gives shelf-________ liquid products such as UHT milk that require no refrigeration before opening.

3.1.3 Chemical and biological methods of preservation

Chemical preservatives: salt (sodium chloride) lowers water activity and inhibits bacterial growth; nitrite (100 to 150 ppm) inhibits Clostridium botulinum and stabilises colour in cured meats; organic acids (lactic acid, acetic acid) lower pH below the minimum for pathogen growth; antioxidants (vitamin E, BHA, BHT) retard fat oxidation; approved food additives must comply with NAFDAC and Codex Alimentarius standards.

Biological methods: fermentation uses beneficial microorganisms (lactic acid bacteria) to lower pH, produce antimicrobial compounds (lactic acid, bacteriocins), and reduce water activity through salt addition. Examples include wara cheese, nono fermented milk, and fermented fish (eja osan). Smoking introduces antimicrobial compounds (phenols, organic acids, aldehydes) from wood smoke. These methods are often combined (hurdle technology) to achieve preservation beyond what any single method achieves alone.

Fill in the blank: ________ technology combines multiple preservation methods (heat, salt, pH, water activity) to achieve product stability that no single method could achieve at the required intensity.

Figure 3.1: Diagram summarising the major preservation methods for animal products by mechanism

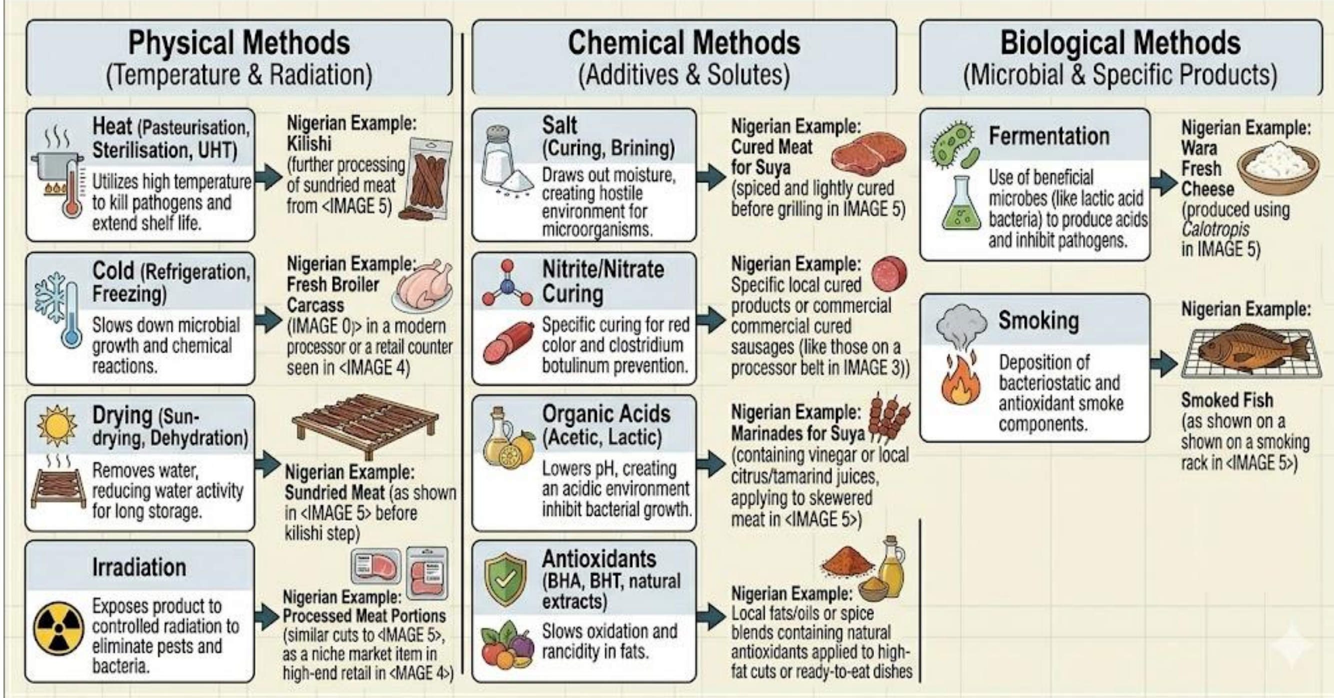

Figure 3.1: Diagram summarising the major preservation methods for animal products by mechanism

Pilot questions 3.1

1. State the three main causes of animal product spoilage and explain each briefly.
2. Distinguish between pasteurisation, sterilisation, and UHT treatment in terms of temperature, time, and effect.
3. Explain how drying preserves animal products and state two drying methods used in Nigeria.
4. State the role of salt in preserving animal products.
5. Explain what hurdle technology is and give one Nigerian example.

3.2 Storage of Animal Products

3.2.1 Refrigeration and freezing storage

Refrigeration storage (0 to 4 degrees Celsius) extends shelf life by slowing microbial growth and enzymatic reactions without freezing the product. This temperature range is used for fresh meat (shelf life 5 to 7 days), pasteurised milk (5 to 7 days), and fresh eggs (4 to 6 weeks). Psychrotrophic bacteria such as Pseudomonas, Listeria monocytogenes, and Yersinia enterocolitica continue to grow at refrigeration temperatures and are the main spoilage organisms in chilled products.

Freezing (minus 18 degrees Celsius or below) provides long-term storage by arresting microbial growth and most enzymatic activity. Shelf life: beef 12 months; poultry 9 months; pork 6 months; fish 3 to 6 months. Quick freezing (blast freezing at minus 30 to minus 40 degrees Celsius) produces small ice crystals that cause minimal cell damage; slow freezing produces large ice crystals that rupture cell membranes and cause drip loss on thawing. Freeze-thaw cycles must be avoided.

Fill in the blank: Quick freezing at minus 30 to minus 40 degrees Celsius produces ________ ice crystals that minimise cell damage and drip loss on thawing compared with slow freezing.

3.2.2 Storage of meat, eggs, and milk

Meat storage: fresh chilled beef is held at 0 to 2 degrees Celsius at 85 to 90 per cent relative humidity; modified atmosphere packaging (MAP) with 60 to 80% CO_2 and 20 to 40% O_2 extends shelf life to 21 days. Frozen beef is held at minus 18 degrees Celsius. In Nigeria, most retail meat is sold the day of slaughter with no cold chain; cold chain development is the single most important infrastructure improvement needed.

Egg storage: fresh eggs are best stored at 12 to 15 degrees Celsius and 70 to 80 per cent relative humidity with blunt end up; refrigerated storage at 4 degrees Celsius extends shelf life to 4 to 6 weeks. Milk storage: raw milk must be chilled to below 4 degrees Celsius within 2 hours of milking; pasteurised milk is stored at 0 to 4 degrees Celsius; UHT milk is stored at ambient temperature before opening. Dairy fermented products (wara, yoghurt) are stored chilled.

Fill in the blank: Fresh eggs should be stored at 12 to 15 degrees Celsius with the ________ end up to maintain air cell position; refrigeration at 4 degrees Celsius extends shelf life to 4 to 6 weeks.

Product	**Storage Conditions**	**Shelf Life**
Fresh Beef	0–2 °C; 85–90% RH	5–7 days
Frozen Beef	–18 °C	12 months
Fresh Poultry	0–2 °C	1–2 days
Frozen Poultry	–18 °C	9 months
Fresh Whole Eggs	12–15 °C; 70–80% RH; blunt end up	3–4 weeks
Refrigerated Eggs	4 °C	4–6 weeks
Raw Milk	Below 4 °C	2–3 days
Pasteurised Milk	0–4 °C	5–7 days
UHT Milk	Ambient (unopened)	6–12 months

Box 3.1: Recommended storage conditions and shelf life for major animal products

3.2.3 Storage losses and their control

Storage losses occur through four mechanisms. Weight loss (shrinkage): moisture evaporates from exposed surfaces; beef loses 1 to 2 per cent weight per day in a poorly managed chiller; controlled by maintaining high relative humidity (85 to 90%) and minimising air velocity above what is needed for cooling. Microbial spoilage: surface slime, off-odours, and greening from psychrotrophic bacteria; controlled by low temperature, MAP, and good hygiene.

Colour deterioration: myoglobin oxidises from oxymyoglobin (bright red) to metmyoglobin (brown) on meat exposed to air; controlled by MAP (high O_2 or CO_2) or vacuum packaging. Rancidity: fat oxidation produces off-flavours; controlled by antioxidants, vacuum or MAP packaging, and avoiding freeze-thaw cycles. In Nigeria, the most significant storage loss is microbial spoilage caused by inadequate refrigeration; improving cold chain access is the primary loss reduction strategy.

Fill in the blank: Myoglobin oxidises from bright red ________ to brown metmyoglobin when meat is exposed to air; modified atmosphere packaging controls this colour deterioration.

Pilot questions 3.2

1. Distinguish between refrigeration and freezing storage in terms of temperature, shelf life, and effect on microorganisms.
2. Explain why quick freezing produces better quality frozen meat than slow freezing.
3. State the recommended storage conditions for fresh beef, whole eggs, and pasteurised milk.
4. Name four types of storage loss and state one control measure for each.
5. Explain why myoglobin oxidation is a storage loss problem and how it is controlled.

3.3 Hygiene in Animal Product Handling

3.3.1 Personal hygiene of food handlers

Food handlers are a major source of contamination of animal products. Key personal hygiene requirements: wash hands thoroughly with soap and water before handling food, after using the toilet, after touching raw meat, and after any contaminating activity; cover all cuts and wounds with a blue waterproof dressing; exclude workers with diarrhoea, vomiting, or infected skin lesions from food handling areas; no eating, drinking, or smoking in food handling areas.

Protective clothing: food handlers must wear clean white or light-coloured overalls or aprons, head coverings (caps or hairnets) to prevent hair falling into products, rubber or plastic boots in wet areas, and disposable gloves where direct hand-to-product contact occurs. Protective clothing must not be worn outside the processing area. In Nigerian abattoirs, personal hygiene is frequently inadequate; improving food handler training is one of the lowest-cost, highest-impact food safety interventions available.

Fill in the blank: Food handlers must be excluded from food processing areas if they have diarrhoea, ________, or infected skin lesions to prevent pathogen transfer to animal products.

3.3.2 Facility and equipment hygiene

Processing facility design for hygiene: walls and floors should be smooth, impervious, and washable (tiles or sealed concrete); floors should drain to a central gutter or perimeter drain; adequate lighting for inspection; separate areas for raw and cooked products to prevent cross-contamination; potable water supply at all processing points; hand-washing facilities at all entry points and at regular intervals in the processing area.

Cleaning and disinfection procedure: remove gross debris by scraping and sweeping; rinse with water; apply detergent and scrub all surfaces including equipment, floors, drains, and walls; rinse with clean water; apply approved disinfectant (chlorine at 100 to 200 ppm, quaternary ammonium compounds, or peracetic acid) at the correct concentration; rinse; allow to air dry. This sequence must be followed in order; applying disinfectant to uncleaned surfaces is ineffective. Pest control (rodent traps, insect screens) is also essential.

Fill in the blank: Disinfectant applied to a surface still coated with organic matter is ________ because the organic material neutralises the active compound before it can contact the microbial cell.

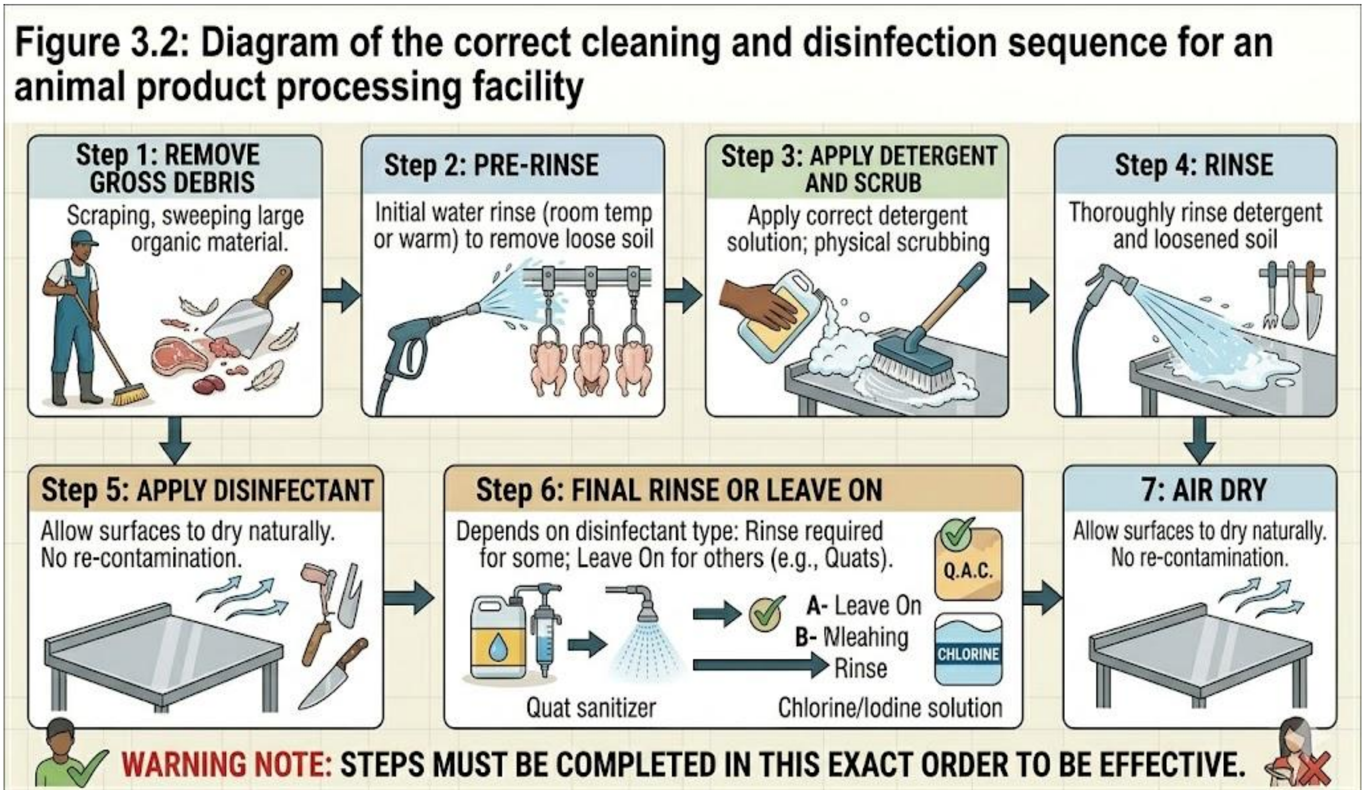

Figure 3.2: Diagram of the correct cleaning and disinfection sequence for a food processing facility

3.3.3 Good Manufacturing Practice

Good Manufacturing Practice (GMP) is a set of documented operational standards that ensure animal products are consistently produced under hygienic conditions. GMP covers: premises and environment (location away from sources of contamination; pest-proof construction); equipment (food-grade materials; easy to clean; properly maintained); personnel (training, health screening, protective clothing); raw material control (approved suppliers, incoming inspection); and process control (standard operating procedures for each processing step).

GMP documentation: Standard Operating Procedures (SOPs) describe how each task is performed; Sanitation Standard Operating Procedures (SSOPs) describe cleaning and disinfection procedures for each area; records of cleaning, temperature monitoring, supplier inspection, and staff training must be maintained. GMP is the prerequisite programme for

HACCP; without GMP in place, HACCP cannot function effectively. NAFDAC requires GMP compliance for all registered food processing operations.

Fill in the blank: Good Manufacturing Practice (________) is the prerequisite programme for HACCP; it covers premises, equipment, personnel, raw materials, and process control in a documented system.

Pilot questions 3.3

1. State five personal hygiene requirements for food handlers working with animal products.
2. Describe the correct sequence for cleaning and disinfecting a meat processing surface.
3. Explain why organic matter must be removed before applying disinfectant.
4. List five components covered by Good Manufacturing Practice.
5. Explain the relationship between GMP and HACCP.

3.4 Foodborne Illness and Safety

3.4.1 Major foodborne pathogens from animal products

Salmonella: the most common bacterial cause of foodborne illness from poultry and eggs in Nigeria; infection causes diarrhoea, fever, and vomiting 6 to 48 hours after consumption; poultry can carry Salmonella without showing signs; destroyed by thorough cooking (above 75 degrees Celsius internal temperature) but raw poultry is a major source of cross-contamination in kitchens and markets.

Escherichia coli O157:H7: a dangerous verotoxin-producing strain associated with undercooked beef and contaminated water; causes haemorrhagic colitis and haemolytic uraemic syndrome (kidney failure) in severe cases. Staphylococcus aureus: causes rapid-onset food poisoning (1 to 6 hours) through heat-stable toxins produced in improperly stored cooked meat, milk, and egg products; the toxin is not destroyed by reheating. Listeria monocytogenes: a psychrotrophic pathogen that grows in chillers; associated with dairy products and ready-to-eat meats; particularly dangerous for pregnant women and immunocompromised individuals.

Fill in the blank: Staphylococcus aureus produces ________ toxins in poorly stored cooked meat and milk; these toxins are not destroyed by reheating and cause food poisoning within 1 to 6 hours of consumption.

3.4.2 Prevention of foodborne illness

The four Cs of food safety: Clean (wash hands, surfaces, and equipment); Cook (heat to safe internal temperature: 75 degrees Celsius for poultry, 70 degrees Celsius for ground beef, 63 degrees Celsius for whole beef cuts); Chill (refrigerate perishables within 2 hours; keep cold chain unbroken); and Cross-contaminate (separate raw from cooked; use different cutting boards and knives for raw meat and ready-to-eat foods).

HACCP (Hazard Analysis and Critical Control Points) is the systematic approach to prevention: identify all biological, chemical, and physical hazards; establish Critical Control Points where control can be applied; set critical limits (e.g. pasteurisation temperature); monitor CCPs; take corrective action when limits are exceeded; keep records; and verify the system. HACCP is mandatory for NAFDAC-registered processors and is required for export market access.

Fill in the blank: The four Cs of food safety are Clean, Cook, Chill, and avoid Cross-________ between raw and ready-to-eat animal products.

Pathogen	**Source**	**Onset Time**	**Prevention Measures**
Salmonella	Poultry, eggs	6–48 hours	Cook above 75 °C; avoid cross-contamination
E. coli O157:H7	Undercooked beef, contaminated water	3–8 hours	Cook ground beef above 70 °C; hygiene at slaughter
Staphylococcus aureus	Cooked meat, milk (improperly stored)	1–6 hours	Chill within 2 hours; maintain cold chain
Listeria monocytogenes	Dairy, ready-to-eat meat	1–30 days	Pasteurise milk; keep chiller below 4 °C; avoid cross-contamination
Campylobacter	Poultry	2–5 days	Thorough cooking; hygiene during processing

Box 3.2: Major foodborne pathogens from animal products: source, onset, and prevention

3.4.3 Food safety regulation in Nigeria

NAFDAC (National Agency for Food and Drug Administration and Control): the primary federal food safety authority; registers all commercially processed food products; sets maximum residue limits for veterinary drugs and pesticides; conducts facility inspections and product testing; enforces recall of unsafe products. Processors must obtain a NAFDAC registration number before commercial distribution.

Standards Organisation of Nigeria (SON): sets Nigerian Industrial Standards (NIS) for product quality parameters for meat, milk, and eggs. State ministries of health and agriculture enforce hygiene at abattoirs and markets through meat inspection officers. The Consumer Protection Council (CPC) provides a mechanism for consumer complaints about food safety. Nigeria is also a member of the Codex Alimentarius Commission and is bound by its food safety guidelines for export trade.

Fill in the blank: All commercially processed animal products in Nigeria must carry a ________ registration number on the label before they can be legally distributed and sold.

Pilot questions 3.4

6. Name four foodborne pathogens associated with animal products and state the primary food vehicle for each.
7. Explain why Staphylococcus aureus food poisoning cannot be prevented by reheating food.
8. State the four Cs of food safety and explain each briefly.
9. Define a Critical Control Point and give one example from meat or milk processing.
10. Describe the role of NAFDAC in food safety regulation in Nigeria.

Series Summary

This Series covered preservation, storage, hygiene, and food safety. Spoilage arises from microbial activity, enzymatic reactions, and chemical changes (lipid oxidation, browning). Physical preservation methods include heat (pasteurisation, sterilisation, UHT), cold (refrigeration, freezing), drying, and irradiation. Chemical methods include salt, nitrite, organic acids, and antioxidants. Biological methods include fermentation and smoking. Hurdle technology combines methods for greater effectiveness.

Storage: refrigeration (0 to 4 degrees Celsius) extends short-term shelf life; quick freezing (minus 18 degrees Celsius) gives months-long storage with less drip loss than slow freezing. Storage losses include shrinkage, microbial spoilage, colour change, and rancidity. Personal hygiene (handwashing, protective clothing, health exclusions), facility hygiene (cleaning and disinfection sequence), and GMP are prerequisite controls. Key foodborne pathogens include Salmonella, E. coli O157:H7, S. aureus, Listeria, and Campylobacter. Prevention uses the four Cs (Clean, Cook, Chill, no Cross-contamination) and HACCP. NAFDAC and SON regulate product safety and quality. By completing this Series, you should achieve all eight SLOs (3.1 to 3.8).

Glossary of Terms

- **Antioxidant:** a compound that retards lipid oxidation (rancidity) in animal products; examples include vitamin E, BHA, and BHT; must comply with permitted additive levels.
- **Blast freezing:** rapid freezing at minus 30 to minus 40 degrees Celsius using high-velocity cold air; produces small ice crystals and minimises drip loss on thawing.
- **Campylobacter:** a bacterial pathogen commonly carried by poultry; causes gastroenteritis 2 to 5 days after consumption; controlled by thorough cooking and processing hygiene.
- **Critical Control Point (CCP):** a step in a food process where a control measure can eliminate or reduce a hazard to an acceptable level; example: pasteurisation temperature for milk.
- **Cross-contamination:** transfer of pathogens from a contaminated source (raw meat, soiled hands, or equipment) to a ready-to-eat product; a major cause of foodborne illness.

- **Drip loss:** water and dissolved nutrients released from thawed frozen meat when ice crystals formed during freezing rupture muscle cell membranes.
- **Fermentation:** a biological preservation method using lactic acid bacteria or other microorganisms to lower pH, produce antimicrobial compounds, and reduce water activity.
- **Four Cs:** the four food safety principles: Clean (handwashing and surface sanitation), Cook (safe internal temperatures), Chill (cold chain maintenance), and avoid Cross-contamination.
- **GMP (Good Manufacturing Practice):** documented operational standards covering premises, equipment, personnel, raw materials, and process control to ensure hygienic production.
- **HACCP:** Hazard Analysis and Critical Control Points; a systematic seven-step food safety management system; mandatory for NAFDAC-registered processors.
- **Hurdle technology:** a preservation strategy combining multiple preservation methods (temperature, water activity, pH, salt) at moderate levels to achieve stability no single method could achieve alone.
- **Listeria monocytogenes:** a psychrotrophic foodborne pathogen that grows in chillers; associated with dairy and ready-to-eat meats; dangerous for pregnant women and immunocompromised persons.
- **MAP (modified atmosphere packaging):** packaging in a gas mixture (CO_2, O_2, N_2) to extend shelf life by inhibiting aerobic spoilage bacteria and controlling colour.
- **Metmyoglobin:** the brown oxidised form of myoglobin in meat exposed to air; indicates loss of freshness; controlled by MAP or vacuum packaging.
- **Mesophile:** a microorganism with an optimum growth temperature of 25 to 40 degrees Celsius; includes most foodborne pathogens and common spoilage bacteria.
- **Pasteurisation:** heat treatment to destroy vegetative pathogens without sterilising the product; for milk: 63 degrees Celsius for 30 minutes (LTLT) or 72 degrees Celsius for 15 seconds (HTST).
- **Psychrotroph:** a microorganism capable of growth at 0 to 7 degrees Celsius; includes Pseudomonas, Listeria, and Yersinia; the main spoilage organisms in chilled products.
- **Salmonella:** a bacterial pathogen in poultry and eggs causing diarrhoea and fever; destroyed by cooking above 75 degrees Celsius; a major cause of Nigerian foodborne illness.

- **Sterilisation (commercial):** heat treatment (121 degrees Celsius, 15 minutes under pressure) that destroys all spores and achieves a commercially sterile product; used for canned animal products.
- **UHT (ultra-high temperature):** heat treatment at 135 to 145 degrees Celsius for 2 to 6 seconds producing a shelf-stable liquid product; used for milk, cream, and fruit juices.
- **Water activity (aw):** the available water in a product; measured on a scale of 0 to 1; most bacteria cannot grow below aw 0.85; lowered by drying, salting, or adding sugar.

Concept Check Questions [Series 3]

Objective Questions

1. The three main causes of animal product spoilage are ________ activity, enzymatic activity, and chemical reactions. (Linked to SLO 3.1)
2. UHT processing at 135 to 145 degrees Celsius for 2 to 6 seconds produces shelf-________ liquid products that require no refrigeration before opening. (Linked to SLO 3.2)
3. Quick freezing at minus 30 to minus 40 degrees Celsius produces small ________ crystals that minimise drip loss on thawing. (Linked to SLO 3.4)
4. Disinfectant applied to a surface still coated with organic matter is ________ because the organic material neutralises the active compound. (Linked to SLO 3.6)
5. All commercially processed animal products in Nigeria must carry a NAFDAC ________ number on the label before they can be legally sold. (Linked to SLO 3.8)

Short-Answer Questions

1. Distinguish between pasteurisation, sterilisation, and UHT treatment. (Linked to SLO 3.2)
2. State the recommended storage conditions for fresh beef, whole eggs, and pasteurised milk. (Linked to SLO 3.4)
3. State five personal hygiene requirements for food handlers. (Linked to SLO 3.6)
4. State the four Cs of food safety and briefly explain each. (Linked to SLO 3.8)
5. Describe the role of NAFDAC in food safety regulation in Nigeria. (Linked to SLO 3.8)

Long-Answer Questions

1. Describe the causes of animal product spoilage and explain the major physical, chemical, and biological preservation methods. (Linked to SLOs 3.1, 3.2, 3.3)
2. Describe the principles of refrigeration and freezing storage, explain storage losses and their control, and describe the storage conditions for meat, eggs, and milk. (Linked to SLOs 3.4, 3.5)
3. Describe personal and facility hygiene requirements, Good Manufacturing Practice, the major foodborne pathogens from animal products, and the food safety regulatory framework in Nigeria. (Linked to SLOs 3.6, 3.7, 3.8)

Answers to Concept Check Questions [Series 3]

Objective Questions

1. Microbial.
2. Stable.
3. Ice.
4. Ineffective.
5. Registration.

Short-Answer Questions

1. Pasteurisation destroys vegetative pathogens (63 degrees Celsius/30 min or 72 degrees Celsius/15 sec for milk); product still requires refrigeration. Sterilisation destroys all spores (121 degrees Celsius/15 min under pressure); product is shelf-stable. UHT destroys spores using extreme short heat (135 to 145 degrees Celsius/2 to 6 sec); shelf-stable liquid product.
2. Fresh beef: 0 to 2 degrees Celsius; 85 to 90% RH; 5 to 7 days. Whole eggs: 12 to 15 degrees Celsius; 70 to 80% RH; blunt end up; 3 to 4 weeks. Pasteurised milk: 0 to 4 degrees Celsius; 5 to 7 days.

3. Wash hands thoroughly before handling food and after using the toilet; cover cuts with blue waterproof dressings; exclude workers with diarrhoea or infected lesions; wear clean overalls and head covering; no eating, drinking, or smoking in processing areas.
4. Clean (wash hands and surfaces); Cook (heat to safe internal temperature: 75 degrees Celsius for poultry, 70 degrees Celsius for ground beef); Chill (refrigerate within 2 hours; maintain cold chain); Cross-contamination (separate raw meat from ready-to-eat foods).
5. NAFDAC registers all commercially processed food products; sets maximum residue limits for veterinary drugs; inspects processing facilities for GMP compliance; tests products for safety; enforces recalls of unsafe products.

Long-Answer Questions

1. Spoilage causes: microbial (bacteria, moulds, yeasts produce putrefaction, rancidity, gas, sliminess); enzymatic (endogenous lipases and proteases cause texture and flavour deterioration); chemical (lipid oxidation causes rancidity; Maillard browning occurs during heating or storage). Physical methods: heat (pasteurisation destroys vegetative pathogens; sterilisation destroys spores; UHT gives shelf-stable liquids); cold (refrigeration 0 to 4 degrees Celsius slows microbes; freezing below minus 18 degrees Celsius arrests growth); drying (reduces aw below 0.85; sun drying, spray drying for fish, meat, milk powder); irradiation (gamma rays destroy pathogens without heat). Chemical methods: salt (lowers aw); nitrite (100 to 150 ppm; inhibits C. botulinum; pink colour; antioxidant); organic acids (lactic, acetic; lower pH); antioxidants (BHA, BHT, vitamin E; retard rancidity). Biological methods: fermentation (lactic acid bacteria lower pH; produce antimicrobial compounds; wara, nono, fermented fish); smoking (phenols, organic acids from wood smoke are antimicrobial). Hurdle technology combines methods for greater effectiveness at lower individual intensities.
2. Refrigeration (0 to 4 degrees Celsius): slows but does not stop microbial growth; shelf life fresh beef 5 to 7 days, pasteurised milk 5 to 7 days, eggs 4 to 6 weeks. Psychrotrophic bacteria (Pseudomonas, Listeria, Yersinia) continue to grow. Freezing (minus 18 degrees Celsius): arrests microbial growth and most enzymatic activity; beef 12 months, poultry 9 months, pork 6 months, fish 3 to 6 months. Quick freezing (minus 30 to minus 40 degrees Celsius) produces small ice crystals, less drip loss than slow freezing. Avoid freeze-thaw cycles. Storage conditions: fresh beef (0 to 2 degrees Celsius; 85 to 90% RH; 5 to 7 days);

whole eggs (12 to 15 degrees Celsius; blunt end up; 3 to 4 weeks); pasteurised milk (0 to 4 degrees Celsius; 5 to 7 days); UHT milk (ambient unopened; 6 to 12 months). Storage losses: weight loss (moisture evaporation; controlled by 85 to 90% RH); microbial spoilage (slime, off-odours; controlled by temperature and MAP); colour change (oxymyoglobin to metmyoglobin; controlled by MAP or vacuum); rancidity (fat oxidation; controlled by antioxidants and packaging). Nigeria primary loss cause is inadequate refrigeration.

3. Personal hygiene: wash hands before food handling and after toilet; cover wounds with blue waterproof dressing; exclude workers with diarrhoea, vomiting, or infected lesions; wear clean overalls, headcovering, boots, and gloves; no eating or smoking in processing areas. Facility hygiene sequence: remove gross debris; pre-rinse; apply detergent and scrub; rinse; apply disinfectant (chlorine 100 to 200 ppm or quaternary ammonium); rinse; air dry. Organic matter must be removed first as it neutralises disinfectant. Pest control (rodent traps, insect screens). GMP covers premises (smooth washable surfaces, adequate lighting, separate raw and cooked areas); equipment (food-grade materials, easy to clean); personnel (training, health screening, protective clothing); raw materials (approved suppliers, incoming inspection); and process control (documented SOPs and SSOPs, temperature records). GMP is the prerequisite for HACCP. Foodborne pathogens: Salmonella (poultry and eggs; 6 to 48 hours; cook above 75 degrees Celsius); E. coli O157:H7 (undercooked beef; haemorrhagic colitis; cook above 70 degrees Celsius); S. aureus (cooked meat and milk stored improperly; heat-stable toxins; 1 to 6 hours; chill within 2 hours); Listeria (dairy, ready-to-eat meats; grows at chiller temperature; pasteurise milk); Campylobacter (poultry; 2 to 5 days; thorough cooking and processing hygiene). Prevention: four Cs. Regulation: NAFDAC registers products and inspects facilities; SON sets NIS quality standards; state meat inspectors enforce abattoir hygiene; CPC handles consumer complaints; Nigeria is a Codex member.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Three causes: (1) Microbial activity (bacteria, moulds, yeasts produce enzymes that break down protein causing putrefaction, and fat causing rancidity; they also produce gas, sliminess, and toxins); (2) Enzymatic activity (endogenous enzymes in muscle and milk continue after slaughter or secretion; lipases cause rancidity; proteases cause texture loss;

desirable during conditioning but excessive activity causes spoilage); (3) Chemical reactions (lipid oxidation by oxygen causes rancid off-flavours independently of microbes; Maillard browning between amino acids and sugars during heating or storage causes colour and flavour changes).

2. Pasteurisation: 63 degrees Celsius for 30 minutes (LTLT) or 72 degrees Celsius for 15 seconds (HTST) for milk; destroys vegetative pathogens but not spores; product requires refrigeration after treatment; shelf life 5 to 7 days. Sterilisation: 121 degrees Celsius for 15 minutes under pressure (retort); destroys all vegetative cells and spores; product is commercially sterile and shelf-stable at ambient temperature for over 12 months; used for canned meat and fish. UHT: 135 to 145 degrees Celsius for 2 to 6 seconds; destroys all pathogens and spores using brief extreme heat with minimal product damage; aseptically packaged into sterile cartons; shelf-stable at ambient temperature for 6 to 12 months.
3. Drying preserves animal products by removing moisture and reducing water activity (aw) to below 0.85, the minimum at which most bacteria can grow. At aw below 0.85 most bacteria cannot replicate; below 0.70 moulds are also inhibited. Two drying methods in Nigeria: (1) Sun drying (placing thinly sliced meat or fish on raised racks in direct sunlight; airflow and solar heat evaporate moisture; used for kilishi, dried fish, and stockfish rehydration); (2) Smoking (hot smoking passes smoke and heat over the product simultaneously, drying and depositing antimicrobial smoke compounds; used for smoked catfish, smoked chicken, and suya).
4. Salt (sodium chloride) preserves animal products through two mechanisms: (1) Osmotic dehydration and water activity reduction (salt dissolves in the moisture of the product and binds water molecules, reducing the free water available for microbial growth; at concentrations of 10 to 20% salt, aw falls below 0.90, inhibiting most spoilage bacteria and many pathogens; in kilishi and cured meats, the salt applied to the surface draws moisture out of the tissue by osmosis, further reducing internal aw); (2) Direct antimicrobial effect (high salt concentrations disrupt bacterial cell membranes and denature intracellular enzymes by ionic interference, inhibiting cell function even in cells that can tolerate moderate aw reduction; halotolerant bacteria such as Staphylococcus aureus can grow at up to 10% NaCl, so salt alone is not sufficient for complete safety and is usually combined with other hurdles).
5. Hurdle technology is a preservation strategy that combines multiple preservation methods (hurdles) at moderate intensities, creating a set of simultaneous stresses that inhibit microbial growth more effectively than any single method applied at the same total intensity. Nigerian example: kilishi production combines three hurdles: (1) salt (sodium chloride in the

groundnut paste marinade lowers aw and directly inhibits bacteria); (2) drying (sun-drying removes moisture, further lowering aw below 0.85); (3) spices (ginger, pepper, cloves contain essential oils with antimicrobial activity against surface bacteria). Each hurdle alone would require a more extreme treatment to achieve stability; together they produce a shelf-stable product at ambient temperature that individual methods at moderate levels could not achieve.

Part 3.2

1. Refrigeration (0 to 4 degrees Celsius): slows microbial growth and enzymatic activity but does not stop them; psychrotrophic bacteria (Pseudomonas, Listeria, Yersinia) continue to grow slowly; shelf life: fresh beef 5 to 7 days, pasteurised milk 5 to 7 days, eggs 4 to 6 weeks; product texture, colour, and nutritional quality are largely preserved; suitable for short-term distribution. Freezing (minus 18 degrees Celsius or below): arrests microbial growth completely (bacteria become dormant but are not killed); most enzymatic activity is halted; chemical reactions slow greatly; shelf life: beef 12 months, poultry 9 months, pork 6 months, fish 3 to 6 months; suitable for long-term storage and long-distance distribution.
2. Quick freezing (blast freezing at minus 30 to minus 40 degrees Celsius) produces better quality frozen meat for the following reason: the rate of freezing determines the size of ice crystals formed in the muscle tissue. In quick freezing, the product passes through the critical temperature zone (minus 1 to minus 5 degrees Celsius, where most ice crystal formation occurs) very rapidly; the large number of ice nucleation sites simultaneously active leads to the formation of many small ice crystals distributed uniformly within the muscle cells and in the extracellular spaces; these small crystals fit within and between muscle fibres without rupturing the cell membranes. In slow freezing, the product passes through the critical zone slowly; few nucleation sites are active at any moment, allowing existing ice crystals to grow large; large ice crystals physically puncture and rupture the muscle cell membranes; when the product thaws, the ruptured cells release their contents as drip loss (a nutrient-rich, red-tinged liquid); this drip loss represents a reduction in product weight, protein content, colour, and sensory quality. Quick freezing therefore preserves texture, colour, and nutritional value significantly better than slow freezing.
3. Fresh beef: 0 to 2 degrees Celsius; relative humidity 85 to 90 per cent; shelf life 5 to 7 days for unpacked beef or up to 21 days with MAP (60 to 80% CO_2). Whole eggs: 12 to 15 degrees Celsius; relative humidity 70 to 80 per cent; blunt end up to maintain the air cell in its

correct position; shelf life 3 to 4 weeks at these conditions; refrigerating at 4 degrees Celsius extends shelf life to 4 to 6 weeks. Pasteurised milk: 0 to 4 degrees Celsius; shelf life 5 to 7 days in sealed packaging; every degree above 4 degrees Celsius significantly reduces shelf life due to residual psychrotrophic bacteria.

4. Four storage losses and controls: (1) Weight loss (shrinkage from moisture evaporation): controlled by maintaining relative humidity at 85 to 90% and minimising air velocity above cooling requirements; wrapping or MAP also prevents surface desiccation. (2) Microbial spoilage (slime, off-odours, greening): controlled by maintaining temperature below 4 degrees Celsius, using MAP with CO2, ensuring good hygiene before storage, and maintaining cold chain without breaks. (3) Colour deterioration (metmyoglobin browning in meat): controlled by MAP with high oxygen (60 to 80% O2 for retail display) or vacuum packaging to exclude oxygen; antioxidants in feed or processing retard oxidation. (4) Rancidity (lipid oxidation producing off-flavours): controlled by vacuum or MAP packaging, antioxidant additives (BHA, BHT, vitamin E), avoiding freeze-thaw cycles, and minimising storage time and temperature.
5. Myoglobin is the oxygen-binding muscle pigment that gives meat its colour. In fresh meat exposed to oxygen, myoglobin is in the oxygenated form called oxymyoglobin, which is a bright cherry-red colour; this is the colour consumers associate with fresh, high-quality meat. When meat is stored and exposed to air over time, the iron in the myoglobin molecule is oxidised from the ferrous (Fe2+) state to the ferric (Fe3+) state, converting oxymyoglobin to metmyoglobin, which is brown in colour; this brown discolouration signals apparent loss of freshness to the consumer and reduces consumer purchase intent and price achieved. Controls: modified atmosphere packaging with high oxygen (60 to 80%) delays metmyoglobin formation in retail display by maintaining constant oxygenation of the myoglobin; vacuum packaging excludes oxygen entirely, preventing metmyoglobin formation during storage and transport; antioxidants (particularly vitamin E fed to animals in the weeks before slaughter) are incorporated into muscle membranes and slow the rate of myoglobin oxidation after slaughter.

Part 3.3

1. Five personal hygiene requirements: (1) Thorough handwashing with soap and water for at least 20 seconds before handling any food product, after using the toilet, after handling raw

meat, and after any activity that could contaminate hands (touching the face, handling waste, using a phone); (2) Cover all cuts, wounds, and skin lesions on the hands and arms with a blue waterproof dressing before handling food; blue colour allows detection if the dressing falls into a product; (3) Workers suffering from diarrhoea, vomiting, jaundice, or skin infections must be excluded from all food handling and processing areas and must report their condition to their supervisor; they may return only after medical clearance; (4) Wear clean, light-coloured protective clothing including overalls or aprons, head coverings (caps or hairnets) that contain all hair, and rubber or plastic boots in wet processing areas; change clothing if it becomes visibly contaminated; (5) No eating, drinking, chewing gum, or smoking in any food handling or processing area; these activities contaminate hands and can deposit mouth bacteria directly onto product surfaces.

2. Correct sequence for cleaning and disinfecting a meat processing surface: (1) Remove gross debris: scrape off all visible meat trim, fat, bone fragments, and blood from the surface using a plastic or stainless steel scraper; sweep or shovel floor debris; this step removes the bulk of the organic material before water is applied; (2) Pre-rinse: flush the surface with cold or lukewarm water (not hot, as hot water cooks protein onto surfaces) to remove loose debris; (3) Apply detergent and scrub: apply a food-safe alkaline detergent at the manufacturer's recommended concentration; scrub all surfaces (including joints, crevices, drainage channels, and equipment underframes) with brushes to emulsify and suspend the remaining fat and protein; allow the detergent contact time specified by the manufacturer; (4) Rinse: flush with potable water to remove all detergent residue; (5) Apply disinfectant: apply an approved disinfectant (chlorine at 100 to 200 ppm, quaternary ammonium compound at the manufacturer's dilution, or peracetic acid) at the correct concentration and contact time; (6) Final rinse (if required by the disinfectant type): some disinfectants must be rinsed off before food contact; quaternary ammonium compounds may be left on surfaces at no-rinse concentrations; follow product instructions; (7) Air dry: allow the surface to air dry; wet surfaces promote rapid recontamination.
3. Organic matter (protein, fat, blood, food residues) must be removed before applying disinfectant for three reasons: (1) Physical barrier: a layer of organic material on a surface prevents the disinfectant from physically contacting the microbial cell; bacteria embedded in a film of protein and fat are shielded from the disinfectant solution even when the surface is flooded with it; (2) Chemical neutralisation: chlorine-based disinfectants (the most commonly used) react with organic nitrogen-containing compounds in a process called chlorine demand; the available chlorine is consumed by reacting with the organic matter before it can attack

bacterial cells; a surface with heavy organic contamination can consume the entire effective concentration of a standard chlorine disinfectant solution, leaving no active chlorine to kill bacteria; (3) Biofilm protection: bacteria in a biofilm (a complex community of microorganisms encased in a polysaccharide matrix adhered to a surface) are hundreds to thousands of times more resistant to disinfectants than planktonic cells; mechanical scrubbing with detergent during the cleaning steps physically disrupts biofilms and removes them from the surface; disinfectant applied without prior cleaning cannot penetrate the biofilm matrix.

4. Five GMP components: (1) Premises and environment (the processing facility must be located away from sources of contamination such as refuse dumps or flooding areas; construction must be pest-proof with sealed walls, windows with insect screens, and rodent-proof drainage; floors, walls, and ceilings must be smooth, impervious, and easily cleaned); (2) Equipment (all equipment in contact with food must be made of food-grade materials, free from cracks and crevices that trap food particles, designed for easy disassembly and cleaning, and maintained in good repair; worn or corroded equipment is a contamination risk); (3) Personnel (all food handlers must receive documented food hygiene training; health screening must be performed on employment and periodically; personal hygiene requirements must be enforced through supervision); (4) Raw material control (raw materials must be sourced from approved suppliers with documented quality assurance systems; each incoming delivery must be inspected for quality, temperature, and condition and accepted or rejected before use; records of all incoming materials must be maintained); (5) Process control (Standard Operating Procedures must document how each processing step is performed; Sanitation Standard Operating Procedures document the cleaning and disinfection of each area; critical parameters such as pasteurisation temperature, chiller temperature, and product pH must be monitored and recorded).
5. GMP (Good Manufacturing Practice) is the prerequisite programme that establishes the basic hygienic and operational conditions required for safe food production; it addresses the production environment (premises, equipment, personnel, raw materials, cleaning) rather than specific food safety hazards in the product. HACCP (Hazard Analysis and Critical Control Points) is a systematic product-specific analysis that identifies the biological, chemical, and physical hazards that could cause harm in a particular food and establishes specific control measures at the Critical Control Points in the process where those hazards can be eliminated or reduced to safe levels. The relationship is hierarchical: GMP must be fully implemented and verified as functioning before HACCP can be applied; if the production environment is not under hygienic control (dirty surfaces, untrained staff, contaminated water, pest activity),

any HACCP plan built on that foundation will fail because the prerequisite conditions assumed by the HACCP analysis do not actually exist; NAFDAC requires both GMP compliance and a HACCP plan from processors applying for product registration.

Part 3.4

1. Four pathogens and food vehicles: (1) Salmonella: primary vehicle is poultry meat and eggs (broiler and layer flocks carry Salmonella asymptomatically; carcasses are contaminated during evisceration; eggs may be internally contaminated via transovarian transmission from infected hens or externally contaminated via cracked or unwashed shells); (2) E. coli O157:H7: primary vehicle is undercooked ground (minced) beef (the pathogen resides in cattle intestines without causing disease; contamination of carcasses occurs during evisceration; grinding mixes surface contamination throughout the product, requiring thorough cooking to all parts of the product to above 70 degrees Celsius); (3) Staphylococcus aureus: primary vehicle is cooked meat and poultry, dairy products, and egg-based foods that are handled after cooking and stored at ambient temperature (the pathogen comes from food handler nasal passages and skin; it grows and produces toxin when food is held between 10 and 45 degrees Celsius); (4) Listeria monocytogenes: primary vehicle is ready-to-eat dairy products (soft cheeses, unpasteurised milk, butter) and ready-to-eat sliced deli meat (the pathogen grows at chiller temperatures below 4 degrees Celsius and can survive pasteurisation conditions if numbers are very high).
2. Staphylococcus aureus food poisoning cannot be prevented by reheating food because the pathogen produces its toxins (enterotoxins A through E and others) in the food before it is reheated. The toxins are proteins but they are unusually heat-stable: they withstand boiling at 100 degrees Celsius for 30 minutes and even autoclaving at 121 degrees Celsius for several minutes. By contrast, the bacterial cells themselves are destroyed by heating to 70 degrees Celsius or above; so reheating a contaminated food to a safe temperature will kill all the S. aureus bacteria present but will leave the pre-formed heat-stable enterotoxins intact in the food; a person consuming the reheated food will ingest the toxins and develop food poisoning (vomiting and diarrhoea within 1 to 6 hours) even though laboratory testing would show the food to be microbiologically "negative" for live bacteria. Prevention must therefore focus on preventing toxin production in the first place: do not allow cooked food to remain between 10

and 45 degrees Celsius for more than 2 hours; chill within 2 hours of cooking; ensure food handlers with nasal infections or skin lesions on the hands do not handle ready-to-eat food.

3. The four Cs of food safety: (1) Clean: wash hands thoroughly with soap for at least 20 seconds before handling food, after using the toilet, and after handling raw meat; clean and sanitise all surfaces and equipment that contact food using the correct cleaning and disinfection sequence; clean does not mean disinfected unless both steps are completed properly. (2) Cook: heat animal products to safe internal temperatures that destroy foodborne pathogens; specific targets are 75 degrees Celsius at the thickest point for poultry, 70 degrees Celsius for ground beef, and 63 degrees Celsius for whole beef and pork cuts; use a calibrated thermometer to verify internal temperature rather than relying on colour alone, as pink colour is not a reliable indicator of undercooking in some species and some cuts. (3) Chill: refrigerate all perishable animal products within 2 hours of cooking or purchase (or within 1 hour if ambient temperature exceeds 32 degrees Celsius); maintain refrigerator temperature at 4 degrees Celsius or below; maintain freezer at minus 18 degrees Celsius; never thaw frozen meat at room temperature (thaw in the refrigerator, in cold running water, or in the microwave immediately before cooking). (4) Cross-contamination: keep raw meat, poultry, seafood, and eggs physically separate from ready-to-eat foods at all stages of storage, preparation, and serving; use separate designated cutting boards and knives for raw meat and for ready-to-eat vegetables and cooked products; store raw meat on the lowest shelf of the refrigerator so that drip does not contaminate foods below.
4. A Critical Control Point is a specific step, point, or procedure in a food processing operation where a control measure can be applied to prevent, eliminate, or reduce a food safety hazard to an acceptable level; it is distinguished from other control measures by the fact that loss of control at this point would result in an unacceptable food safety risk to the consumer. Example from milk processing: pasteurisation is a CCP in milk processing. The hazard being controlled is vegetative bacterial pathogens (Salmonella, Brucella, Listeria, Campylobacter, E. coli O157:H7). The critical limit is a minimum temperature of 72 degrees Celsius held for a minimum of 15 seconds (HTST pasteurisation) or 63 degrees Celsius for 30 minutes (LTLT); these are the scientifically validated conditions that achieve a 5-log reduction in the target pathogen (Coxiella burnetii, the most heat-resistant pathogen of concern in raw milk). The monitoring procedure is continuous temperature and time recording by the pasteuriser's chart recorder, with automatic diversion of under-processed milk back for reprocessing if the temperature falls below the critical limit. Records of every pasteurisation run are retained for a minimum of 2 years.

5. NAFDAC (National Agency for Food and Drug Administration and Control) is the primary federal regulatory authority for food safety in Nigeria. Its roles include: (1) Product registration: all commercially manufactured, imported, or exported food products (including processed meat, dairy, and egg products) must be registered with NAFDAC before they can be legally sold; the manufacturer submits product composition, manufacturing process, packaging, shelf life data, and laboratory test results for review; NAFDAC assigns a unique registration number that must appear on the label of every batch produced. (2) Facility inspection: NAFDAC inspectors conduct announced and unannounced inspections of food processing facilities to verify GMP and HACCP compliance; facilities that fail to meet standards are issued warning letters, required to implement corrective actions within specified timeframes, or are closed if hazards are immediate. (3) Maximum residue limits: NAFDAC sets and enforces limits for veterinary drug residues (antibiotics, anthelmintics, growth promoters) and pesticide residues in animal products; products exceeding MRLs are recalled and the producer may be prosecuted. (4) Market surveillance and enforcement: NAFDAC samples products from market shelves and tests them for microbiological safety, chemical adulteration, and counterfeit or unregistered status; products failing tests are seized and destroyed; producers of substandard products are prosecuted under the NAFDAC Act.

References and Attributions [Series 3]

Textual References (Books and External Sources)

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Figures, Plates, Tables, and Boxes

- Figure 3.1: Major preservation methods diagram Attribution: AI generated. Suggested OER search string: "animal product preservation methods physical chemical biological Nigeria diagram OER".
- Box 3.1: Storage conditions and shelf life for animal products Attribution: AI generated. Suggested OER search string: "storage conditions shelf life meat eggs milk animal products OER box".
- Figure 3.2: Cleaning and disinfection sequence diagram Attribution: AI generated. Suggested OER search string: "cleaning disinfection sequence food processing facility steps diagram OER".
- Box 3.2: Major foodborne pathogens from animal products summary Attribution: AI generated. Suggested OER search string: "foodborne pathogens animal products Salmonella Listeria E. coli Staphylococcus Campylobacter OER box".

Course code: AGE 408

Course title: Animal Products Handling, Processing and Storage

Course credit load: 2 Units

Series 4: Milk, Eggs, and By-Products Processing and Quality

- **Part 4.1: Milk Composition and Quality Assessment**
  - Sub Part 4.1.1: Composition and nutritional value of milk
  - Sub Part 4.1.2: Milk quality tests and standards
  - Sub Part 4.1.3: Adulteration of milk and its detection
- **Part 4.2: Milk Processing and Dairy Products**
  - Sub Part 4.2.1: Pasteurisation and UHT processing of milk
  - Sub Part 4.2.2: Fermented dairy products
  - Sub Part 4.2.3: Butter, cheese, and dried milk manufacture
- **Part 4.3: Egg Composition, Quality, and Processing**
  - Sub Part 4.3.1: Composition and nutritional value of eggs
  - Sub Part 4.3.2: Egg quality assessment
  - Sub Part 4.3.3: Egg grading, handling, and processing
- **Part 4.4: Animal By-Products Processing and Utilisation**
  - Sub Part 4.4.1: Blood, bone, and feather processing
  - Sub Part 4.4.2: Hides, skins, and fat processing
  - Sub Part 4.4.3: Economic importance of by-products

Introduction

Milk and eggs are the most widely consumed animal products in Nigeria after meat. Both are nutritionally dense, biologically perishable, and require specific handling and processing to remain safe and marketable. Animal by-products such as blood, bone, feathers, and fat represent additional economic value that is frequently lost in informal processing systems.

This Series covers milk composition and quality testing, pasteurisation and dairy product manufacture, egg composition and quality assessment, egg grading and processing, and the processing and economic value of animal by-products. These topics connect the production and slaughter stages covered in earlier Series to the consumer marketplace.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** describe the composition and nutritional value of milk and explain the basis of milk quality standards (Linked to Part 4.1),
- **SLO 4.2** describe the methods used to test milk quality and detect adulteration (Linked to Part 4.1),
- **SLO 4.3** describe pasteurisation, UHT processing, and the manufacture of fermented dairy products, butter, cheese, and dried milk (Linked to Part 4.2),
- **SLO 4.4** describe the composition and nutritional value of eggs and explain the methods of egg quality assessment (Linked to Part 4.3),
- **SLO 4.5** describe egg grading, handling, and processing into egg products (Linked to Part 4.3),
- **SLO 4.6** describe the processing of blood, bone, feathers, hides, skins, and fat into useful products (Linked to Part 4.4), and
- **SLO 4.7** explain the economic importance of animal by-product utilisation (Linked to Part 4.4).

4.1 Milk Composition and Quality Assessment

4.1.1 Composition and nutritional value of milk

Whole cow milk contains approximately 87.5% water, 3.5% fat, 3.3% protein (primarily casein and whey proteins), 4.8% lactose, and 0.7% minerals and vitamins. Milk fat provides energy and fat-soluble vitamins A, D, E, and K. Milk proteins are of high biological value, providing all essential amino acids. Calcium in milk is the most bioavailable form available in any common food.

Milk from different species varies in composition. Goat milk has smaller fat globules than cow milk, making it easier to digest. Sheep milk has higher fat (6 to 7%) and protein (5 to 6%) than cow milk and is richer in conjugated linoleic acid. Buffalo milk has the highest fat content (7 to 8%) of common dairy animals. In Nigeria, cow milk is the primary commercial dairy species; goat milk is consumed locally in many northern communities.

Fill in the blank: Whole cow milk contains approximately 87.5% water, 3.5% fat, 3.3% ________, 4.8% lactose, and 0.7% minerals and vitamins.

4.1.2 Milk quality tests and standards

Standard milk quality tests: total plate count (TPC) measures the total number of viable bacteria per millilitre; Grade A raw milk should have TPC below 100,000 cfu/mL before pasteurisation. Somatic cell count (SCC) indicates udder health; a count above 200,000 cells/mL suggests subclinical mastitis. Titratable acidity measures lactic acid produced by bacteria; fresh milk has acidity of 0.14 to 0.18% lactic acid; higher values indicate bacterial spoilage.

Physical tests: the clot on boiling test (a sample boiled in a test tube; clotting indicates high acidity or colostrum contamination, unfit for processing); alcohol test (equal volumes of milk and 70% ethanol mixed; clotting indicates milk too acidic for pasteurisation); specific gravity (measured with a lactometer; normal 1.027 to 1.033; dilution with water lowers specific gravity). Chemical tests: fat content by Gerber or Babcock method; total solids by evaporation. Bacteriological tests: TPC, coliform count, mastitis detection.

Fill in the blank: The ________ test mixes equal volumes of milk and 70 per cent ethanol; clotting indicates the milk is too acidic for pasteurisation and unsuitable for processing.

4.1.3 Adulteration of milk and its detection

Common forms of milk adulteration in Nigeria: water addition (most common; increases volume but lowers fat and protein; detected by lactometer, cryoscopy, or specific gravity); skimming of fat (cream removed before sale; detected by Gerber fat test); addition of starch, sugar, or flour (to restore apparent thickness after dilution; detected by iodine test for starch); addition of formalin or hydrogen peroxide (to extend shelf life; detected by chemical tests; illegal and dangerous).

Antibiotic residues in milk are a serious food safety issue; cows under antibiotic treatment must not supply milk for human consumption during the withdrawal period. Antibiotic presence is detected using rapid test kits (Delvotest, Charm test) at the dairy plant. NAFDAC sets maximum residue limits (MRLs) for antibiotic residues in milk; milk containing residues above MRLs is rejected. Adulteration harms consumers, undermines industry credibility, and is a criminal offence under the NAFDAC Act.

Fill in the blank: Water addition to milk is detected by measuring ________ gravity using a lactometer; normal cow milk has a specific gravity of 1.027 to 1.033; water addition lowers this value.

Pilot questions 4.1

1. State the major components of whole cow milk and the approximate percentage of each.
2. Describe three standard milk quality tests and state the acceptable limit for each.
3. Explain three common forms of milk adulteration and the test used to detect each.
4. Explain why antibiotic residues in milk are a food safety concern.
5. Explain what somatic cell count measures and what a high count indicates.

4.2 Milk Processing and Dairy Products

4.2.1 Pasteurisation and UHT processing of milk

Pasteurisation is the heat treatment of milk to destroy vegetative pathogenic bacteria while preserving most nutritional value and extending shelf life. LTLT (low temperature long time): 63 degrees Celsius for 30 minutes; used in small-scale operations. HTST (high temperature short time): 72 degrees Celsius for 15 seconds; the standard industrial method using continuous plate heat exchangers. After pasteurisation, milk is rapidly cooled to below 4 degrees Celsius and aseptically packed.

UHT (ultra-high temperature) processing at 135 to 145 degrees Celsius for 2 to 6 seconds destroys all pathogens and spores, producing a commercially sterile product that is shelf-stable at ambient temperature for 6 to 12 months when aseptically packed in multi-layer laminate cartons (Tetra Pak). UHT milk is widely consumed in Nigerian urban markets (Hollandia, Peak, Cowbell, and Dano brands). Homogenisation (forcing milk through small nozzles at high pressure) is applied before pasteurisation or UHT to break up fat globules and prevent cream separation.

Fill in the blank: HTST pasteurisation heats milk to 72 degrees Celsius for ________ seconds in a continuous plate heat exchanger; it is the standard industrial pasteurisation method.

Figure 4.1: Flow diagram of the HTST milk pasteurisation process

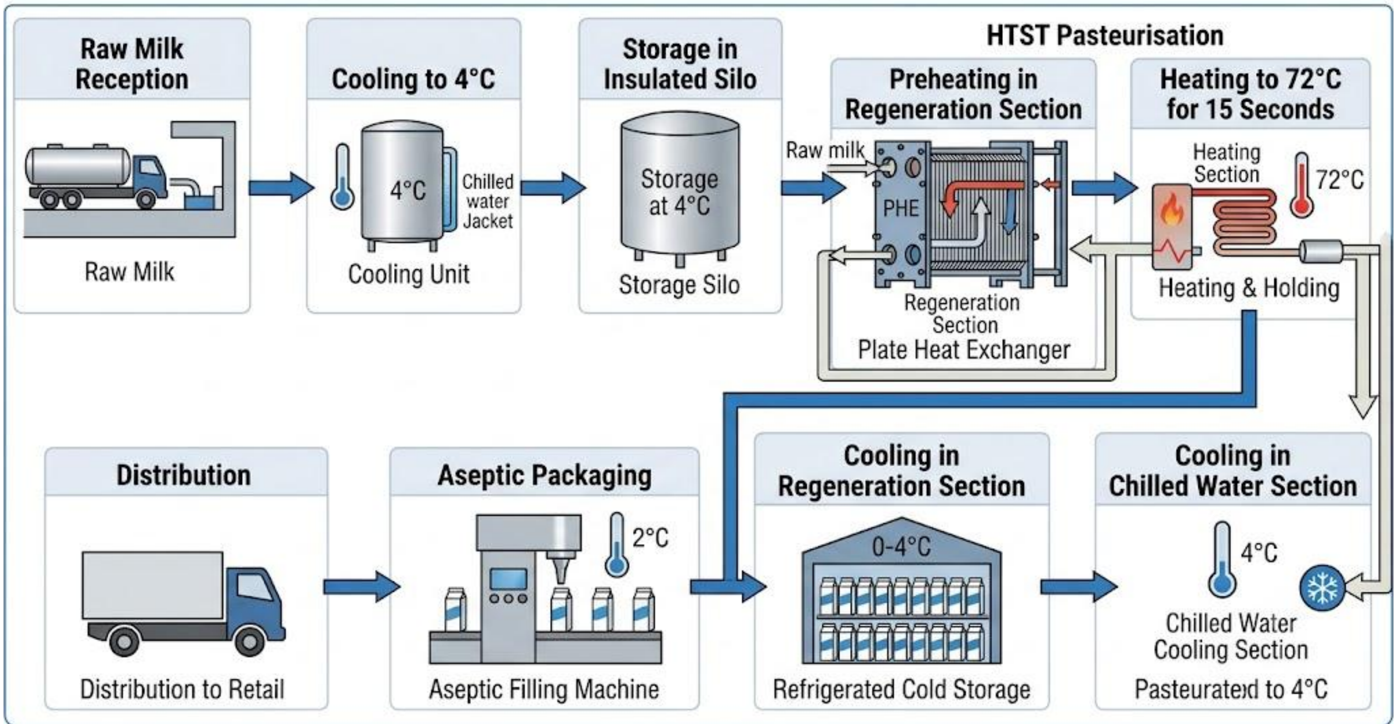

Figure 4.1: Flow diagram of the HTST milk pasteurisation process

4.2.2 Fermented dairy products

Yoghurt is produced by fermenting pasteurised milk with a defined starter culture of Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus at 42 to 45 degrees Celsius for 4 to 6 hours until a pH of 4.2 to 4.4 is reached. The lactic acid coagulates the casein, producing the characteristic thick gel texture. Set yoghurt is fermented in the final container; stirred yoghurt is fermented in a vat and then stirred and packaged. Both are stored at 0 to 4 degrees Celsius.

Traditional Nigerian fermented dairy products: nono (naturally fermented soured milk from Fulani cattle, with no defined starter; sold in calabashes or plastic sachets along northern Nigerian roads); wara (West African soft cheese coagulated with Calotropis procera latex; a fresh, unripened cheese widely consumed in the Middle Belt and north); nunu (a thicker curdled milk product). These traditional products serve millions of Nigerians but are produced without temperature control or defined microbial cultures, posing variable food safety risks.

Fill in the blank: Yoghurt is fermented at 42 to 45 degrees Celsius using a starter culture of Streptococcus thermophilus and Lactobacillus delbrueckii subsp. ________ until the pH falls to 4.2 to 4.4.

4.2.3 Butter, cheese, and dried milk manufacture

Butter: cream (fat content 35 to 40%) is separated from milk by centrifugation; the cream is churned (agitated vigorously) causing fat globule membranes to rupture and the fat to coalesce into butter granules; butter granules are washed, salted (optional), and worked into a smooth mass; butter contains 80% fat, 16 to 18% water, and 2 to 4% milk solids. It is stored at 0 to 4 degrees Celsius and can be frozen for longer storage.

Cheese: milk is coagulated with rennet (an enzyme from calf stomach or microbial equivalent) at 30 to 32 degrees Celsius; the curd is cut, heated, and pressed to expel whey; the pressed curd is salted and ripened for days to years depending on cheese type. Wara is a fresh unripened cheese using Calotropis coagulant. Dried milk: whole milk or skimmed milk is spray-dried (atomised into a hot-air chamber) to produce powder with 2 to 4% moisture and a shelf life of 12 to 24 months at ambient temperature; widely used in Nigerian food manufacturing and household use.

Fill in the blank: Butter contains approximately 80% fat, 16 to 18% ________, and 2 to 4% milk solids; it is produced by churning cream until fat globule membranes rupture and fat coalesces.

Pilot questions 4.2

6. Distinguish between LTLT and HTST pasteurisation in terms of temperature, time, and scale of application.
7. Explain what UHT processing achieves and why UHT milk does not require refrigeration before opening.
8. Describe the production of yoghurt including the starter organisms and incubation conditions.
9. Describe how butter is manufactured from cream.
10. Explain how spray drying produces milk powder and state its shelf life.

4.3 Egg Composition, Quality, and Processing

4.3.1 Composition and nutritional value of eggs

A whole hen egg (approximately 60 g) consists of shell (10%), albumen/white (58%), and yolk (32%) by weight. The albumen is primarily water (88%) and protein (11%), containing ovalbumin, ovotransferrin, lysozyme, and other proteins. Egg white proteins have the highest biological value of any food protein (BV = 100, the international reference standard). The yolk contains fat (33%), protein (17%), and lecithin, as well as fat-soluble vitamins A, D, E, and K and all B vitamins.

The egg yolk is the primary source of cholesterol (approximately 186 mg per egg) and is rich in lutein and zeaxanthin (carotenoids important for eye health). Yolk colour is determined entirely by dietary xanthophylls; pale yolks result from white maize-based diets while deep yellow or orange yolks result from diets containing marigold meal, yellow maize, or paprika. Egg lecithin is a natural emulsifier used widely in food manufacture.

Fill in the blank: Yolk colour is determined by dietary ________ pigments; diets containing marigold meal or yellow maize produce deep yellow yolks while white maize diets produce pale yolks.

4.3.2 Egg quality assessment

External quality assessment: shell integrity (free from cracks, checked by candling or acoustic crack detection); shell cleanliness (absence of faecal contamination or blood stains); egg weight (size classification); shell colour (breed-dependent; no effect on internal quality or nutritional value). A cracked shell allows bacterial entry and rapid internal quality decline; cracked eggs must be separated at collection and processed immediately.

Internal quality assessment: Haugh Unit (HU) measures albumen height relative to egg weight; fresh eggs have HU above 72 (Grade AA); lower HU indicates quality decline from ageing or heat exposure. Yolk index (yolk height to yolk width ratio; fresh 0.40 to 0.42; declines with age). Air cell size (measured by candling; grows as moisture evaporates; small air cell indicates freshness). Blood spots and meat spots are detected by candling and cause downgrading. The Roche colour fan grades yolk colour on a scale of 1 to 15.

Fill in the blank: The Haugh Unit (HU) measures ________ height relative to egg weight; fresh Grade AA eggs have HU above 72; lower values indicate quality loss from ageing or heat.

4.3.3 Egg grading, handling, and processing

Egg grading classifies eggs by size and quality. Size grades: extra large (above 68 g), large (60 to 68 g), medium (53 to 60 g), small (45 to 53 g), and peewee (below 45 g). Quality grades: Grade AA (HU above 72; clean uncracked shell; air cell below 3 mm; firm yolk); Grade A (HU 60 to 72; clean shell; air cell 3 to 6 mm); Grade B (HU below 60; slight stain; larger air cell; for industrial processing). Graded eggs are stamped with a farm code, date, and grade.

Egg processing: pasteurised liquid egg (shell eggs are broken, the contents strained, pasteurised at 60 to 64 degrees Celsius for 2 to 4 minutes, and aseptically packaged as liquid whole egg, liquid white, or liquid yolk); dried egg powder (spray-dried at low temperature to preserve protein functionality; moisture below 5%; shelf life 12 to 24 months); pickled eggs (hard-boiled, peeled, and stored in acidified brine below pH 4.6). In Nigeria, the growing bakery, confectionery, and fast food sectors are increasing demand for liquid and dried egg products.

Fill in the blank: Pasteurised liquid egg is produced by breaking shell eggs, straining the contents, pasteurising at 60 to 64 degrees Celsius for 2 to 4 minutes, and packaging aseptically as liquid whole egg, liquid white, or liquid ________.

Category	**Criteria**	**Details**
Size Grades	Extra Large	>68 g
	Large	60–68 g
	Medium	53–60 g
	Small	45–53 g
	Peewee	<45 g
Quality Grades	Grade AA	HU >72; clean, uncracked shell; air cell <3 mm; firm, centred yolk

	Grade A	HU 60–72; clean, uncracked shell; air cell 3–6 mm; slightly flat yolk
	Grade B	HU <60; slight stains permitted; larger air cell; flat yolk; downgraded for industrial use
Assessment Methods	Candling	Detects cracks, air cell size, blood spots
	Weighing	Determines size grade
	Haugh Unit Measurement	Evaluates albumen quality and freshness

Box 4.1: Egg size grades and quality grades with assessment criteria

Pilot questions 4.3

1. State the approximate composition of a whole hen egg by component (shell, albumen, yolk) and describe the nutritional contribution of each.
2. Explain what the Haugh Unit measures and state the HU values for Grade AA, A, and B eggs.
3. Describe the size and quality grading system for commercial eggs.
4. Describe how pasteurised liquid egg is produced and state its applications.
5. Explain how yolk colour is determined and why it matters commercially.

4.4 Animal By-Products Processing and Utilisation

4.4.1 Blood, bone, and feather processing

Blood: collected during slaughter (4 to 6 litres per cattle); spray-dried or drum-dried into blood meal containing 80 to 85% crude protein; widely used as a high-protein animal feed ingredient. Fresh blood is also used for blood sausage (boudin, black pudding). Blood plasma (separated by centrifugation) is a functional food ingredient used in processed meat products as a binder and emulsifier. In Nigeria, blood is frequently discarded at informal abattoirs, representing a significant protein and income loss.

Bone: fresh bones from the slaughter floor are sterilised under pressure and dried to produce meat and bone meal (50% protein, 30% minerals); used in animal feeds and fertilisers. Bone char (calcined bone) is used in sugar refining and water filtration. Gelatin is extracted from bone and connective tissue by prolonged heating in water; it is used in confectionery, dairy desserts, and pharmaceutical capsules. Feathers: poultry feathers (approximately 6 to 7% of live bird weight) are hydrolysed under pressure with steam to produce hydrolysed feather meal (80% crude protein); used as a low-cost feed ingredient.

Fill in the blank: Blood meal produced by spray-drying or drum-drying livestock blood contains ________ to 85 per cent crude protein and is widely used as a high-protein animal feed ingredient.

4.4.2 Hides, skins, and fat processing

Hides and skins processing was introduced in Series 2. The finished leather value chain: raw salted hide (low value) is tanned into crust leather (vegetable or chrome tanning), then finished (buffed, dyed, coated, embossed), and converted into final products (shoes, bags, gloves, belts). Value increases by 300 to 500% from raw hide to finished leather. Nigeria exports raw and semi-processed hides and skins but imports finished leather goods, representing a missed value addition opportunity.

Animal fats: tallow (from cattle and sheep) and lard (from pigs) are rendered by melting and straining adipose tissue; tallow is used for soap manufacture, candles, and animal feeds; lard is used in baking and cooking. Rendered fat has a long shelf life if stored sealed and away from light. Fishmeal and fish oil: from fish processing waste (heads, frames, viscera); fish oil is used in aquaculture feed and pharmaceutical omega-3 supplements; fishmeal (65 to 70% protein) is the most valuable aquaculture and poultry feed ingredient.

Fill in the blank: Tallow (from cattle and sheep) and lard (from pigs) are produced by ________ adipose tissue; they are used in soap and candle manufacture, animal feeds, and baking.

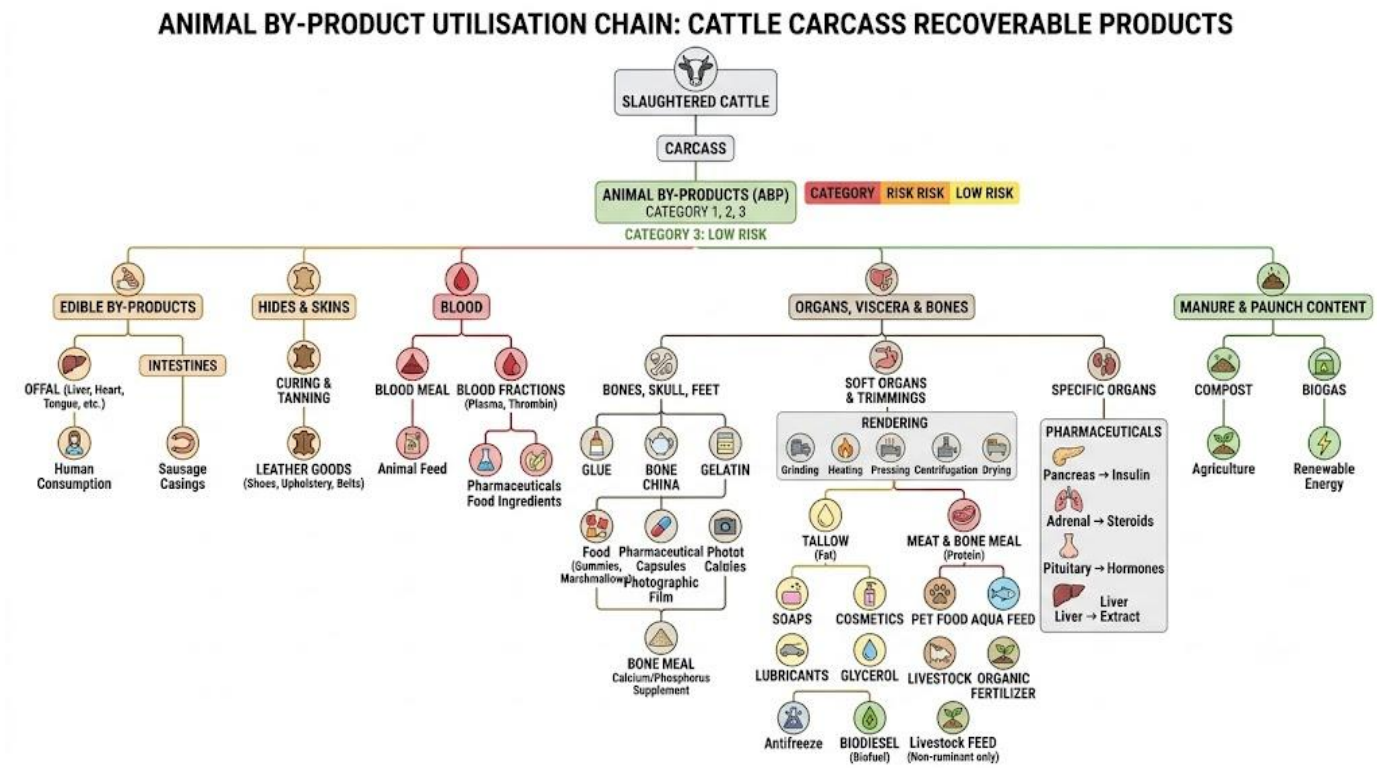

Figure 4.2: Diagram of the animal by-product utilisation chain from slaughter to final product

4.4.3 Economic importance of by-products

By-product utilisation significantly improves the overall economic return from the slaughter operation. In a well-managed abattoir, by-products can contribute 10 to 20% of the total value of the animal beyond the carcass price. Key by-product values: offal (liver, kidneys, tripe) adds 15 to 20% to carcass value and is sold fresh at premium prices in Nigerian markets; hides and skins add 5 to 10% when properly processed; blood meal and bone meal avoid feed ingredient import costs.

In Nigeria, significant by-product value is lost through poor slaughter hygiene (contaminating hides), inadequate bleeding (reducing blood recovery), leaving abattoir waste for scavengers, and lack of rendering facilities for tallow and bone meal. FIIRO (Federal Institute of Industrial Research Oshodi) and IITA have developed protocols for by-product processing. Investment in basic by-product processing infrastructure at state abattoirs would recover substantial economic value currently lost as waste.

Fill in the blank: By-products can contribute ________ to 20 per cent of the total value of a slaughter animal beyond the carcass; offal, hides, blood meal, and bone meal are the most economically significant by-products in Nigeria.

Pilot questions 4.4

1. Describe how blood is processed into blood meal and state its nutritional value.
2. Describe how bones are processed into meat and bone meal and gelatin.
3. Explain why feather meal processing requires hydrolysis rather than simple drying.
4. State four animal fat by-products and the end use of each.
5. Explain why poor by-product utilisation is an economic loss for Nigerian abattoirs.

Series Summary

This Series covered milk, egg, and by-product processing and quality. Milk composition (87.5% water, 3.5% fat, 3.3% protein, 4.8% lactose) and quality tests (TPC, SCC, titratable acidity, alcohol test, lactometer) were described. Adulteration (water addition, fat skimming, starch, formalin) and its detection were explained. Milk processing: HTST pasteurisation (72 degrees Celsius/15 sec), UHT (135 to 145 degrees Celsius/2 to 6 sec), yoghurt fermentation, butter churning, cheese coagulation with rennet, and spray-dried milk powder.

Eggs: composition (shell 10%, albumen 58%, yolk 32%); quality assessment by HU (Grade AA above 72), yolk index, air cell size, and candling; size grading and quality grading (AA, A, B); processed products include pasteurised liquid egg and dried egg powder. By-products: blood meal (80 to 85% CP), meat and bone meal, hydrolysed feather meal, tallow, lard, gelatin, fishmeal, and fish oil. By-products add 10 to 20% to slaughter animal value; Nigeria loses significant by-product value due to poor infrastructure. By completing this Series, you should achieve all seven SLOs (4.1 to 4.7).

Glossary of Terms

- **Albumen:** the white portion of an egg, consisting of 88% water and 11% protein (ovalbumin, ovotransferrin, lysozyme); the highest biological value protein of any food.
- **Blood meal:** a dried animal feed ingredient produced from slaughterhouse blood; contains 80 to 85% crude protein; one of the richest protein feed ingredients available.
- **Butter:** a dairy product containing approximately 80% fat produced by churning cream; the fat globule membranes rupture and fat coalesces into a solid mass.
- **Casein:** the major milk protein (about 80% of total milk protein); coagulates at pH 4.6 and in the presence of rennet; the protein fraction of cheese curd.
- **Churning:** the vigorous agitation of cream that ruptures fat globule membranes, allowing the fat to coalesce into butter granules.
- **Cryoscopy:** measurement of the freezing point of milk; the freezing point is depressed by dissolved solids; water addition raises the freezing point toward that of pure water, revealing adulteration.
- **Gelatin:** a water-soluble protein extracted from collagen in bones and connective tissue by prolonged moist heat; used in confectionery, dairy desserts, and pharmaceutical capsules.
- **Haugh Unit (HU):** a measure of albumen quality calculated from albumen height and egg weight; Grade AA eggs have HU above 72; lower values indicate quality decline.
- **Homogenisation:** forcing milk through small nozzles at high pressure to break fat globules into uniform small particles, preventing cream separation.
- **HTST:** high temperature short time pasteurisation; 72 degrees Celsius for 15 seconds; the standard industrial continuous pasteurisation method for milk.
- **Hydrolysed feather meal:** poultry feathers processed under steam pressure to break keratin disulphide bonds, making the protein digestible; contains approximately 80% crude protein.
- **Lactometer:** an instrument for measuring the specific gravity of milk; used to detect water addition (which lowers specific gravity below the normal 1.027 to 1.033).
- **Lecithin:** a phospholipid concentrated in egg yolk; acts as a natural emulsifier in food products including mayonnaise, chocolate, and processed meats.

- **LTLT:** low temperature long time pasteurisation; 63 degrees Celsius for 30 minutes; a batch method used in small-scale dairy operations.
- **Meat and bone meal:** a by-product of rendering sterilised bones and meat trimmings; contains approximately 50% protein and 30% minerals (calcium and phosphorus); used in animal feeds and fertilisers.
- **Nono:** traditional northern Nigerian naturally fermented soured milk; no defined starter culture; sold by Fulani traders in calabashes or plastic sachets.
- **Rennet:** an enzyme (chymosin) from calf stomach or microbial/fungal equivalent used to coagulate milk casein for cheese making.
- **Somatic cell count (SCC):** the number of white blood cells per millilitre of milk; an indicator of udder health; above 200,000 cells/mL suggests subclinical mastitis.
- **Spray drying:** atomisation of liquid milk or egg into a hot-air chamber to remove moisture instantly; produces powder with 2 to 4% moisture and 12 to 24 months shelf life.
- **Tallow:** rendered fat from cattle and sheep adipose tissue; used for soap manufacture, candle production, and animal feed; high in saturated fatty acids.
- **UHT:** ultra-high temperature processing at 135 to 145 degrees Celsius for 2 to 6 seconds followed by aseptic packaging; produces shelf-stable liquid milk with 6 to 12 months ambient shelf life.
- **Wara:** traditional West African fresh unripened cheese produced by coagulating cow or goat milk with Calotropis procera leaf latex; widely consumed in northern and Middle Belt Nigeria.
- **Yolk index:** the ratio of yolk height to yolk width; fresh eggs have a yolk index of 0.40 to 0.42; declines with age as the vitelline membrane weakens.

Concept Check Questions [Series 4]

Objective Questions

1. Whole cow milk contains approximately 87.5% water, 3.5% fat, 3.3% ________, 4.8% lactose, and 0.7% minerals. (Linked to SLO 4.1)
2. HTST pasteurisation heats milk to 72 degrees Celsius for ________ seconds in a continuous plate heat exchanger. (Linked to SLO 4.3)
3. Fresh Grade AA eggs have a Haugh Unit above ________ ; lower values indicate quality loss from ageing or heat exposure. (Linked to SLO 4.4)
4. Blood meal produced by spray-drying or drum-drying livestock blood contains ________ to 85 per cent crude protein. (Linked to SLO 4.6)
5. By-products can contribute ________ to 20 per cent of the total value of a slaughter animal beyond the carcass price. (Linked to SLO 4.7)

Short-Answer Questions

1. State three standard milk quality tests and the acceptable limit for each. (Linked to SLO 4.2)
2. Distinguish between HTST and UHT milk processing in terms of temperature, time, and shelf life. (Linked to SLO 4.3)
3. Describe yoghurt production including the starter organisms and incubation conditions. (Linked to SLO 4.3)
4. Explain the egg quality grades AA, A, and B and state the Haugh Unit range for each. (Linked to SLO 4.4)
5. Name four animal by-products and state the processed product and end use of each. (Linked to SLO 4.6)

Long-Answer Questions

1. Describe the composition and nutritional value of milk, the major quality tests, and the methods of detecting milk adulteration. (Linked to SLOs 4.1, 4.2)

2. Describe milk pasteurisation and UHT processing, fermented dairy products, and the manufacture of butter, cheese, and dried milk. (Linked to SLO 4.3)
3. Describe the composition and quality assessment of eggs, the grading and processing of eggs, and the processing and economic importance of animal by-products. (Linked to SLOs 4.4, 4.5, 4.6, 4.7)

Answers to Concept Check Questions [Series 4]

Objective Questions

1. Protein.
2. 15.
3. 72.
4. 80.
5. 10.

Short-Answer Questions

1. Total plate count (TPC): below 100,000 cfu/mL for Grade A raw milk. Somatic cell count (SCC): below 200,000 cells/mL. Titratable acidity: 0.14 to 0.18% lactic acid for fresh milk; higher values indicate bacterial spoilage.
2. HTST: 72 degrees Celsius for 15 seconds; destroys vegetative pathogens; requires refrigeration; shelf life 5 to 7 days. UHT: 135 to 145 degrees Celsius for 2 to 6 seconds; destroys pathogens and spores; shelf-stable at ambient temperature; shelf life 6 to 12 months before opening.
3. Pasteurised milk is inoculated with a starter culture of Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus; incubated at 42 to 45 degrees Celsius for 4 to 6 hours until pH falls to 4.2 to 4.4; lactic acid coagulates casein forming the characteristic gel; stored at 0 to 4 degrees Celsius.

4. Grade AA: HU above 72; clean uncracked shell; air cell below 3 mm; firm yolk. Grade A: HU 60 to 72; clean shell; air cell 3 to 6 mm. Grade B: HU below 60; slight stain permitted; larger air cell; downgraded for industrial processing.
5. Blood: spray-dried into blood meal (80 to 85% CP; animal feed). Bone: sterilised and dried into meat and bone meal (50% protein; feed and fertiliser). Feathers: hydrolysed under steam into feather meal (80% CP; animal feed). Offal: sold fresh as edible meat (liver, kidneys, tripe; human consumption).

Long-Answer Questions

1. Milk composition: approximately 87.5% water, 3.5% fat (fat-soluble vitamins A, D, E, K), 3.3% protein (casein and whey; high biological value; all essential amino acids), 4.8% lactose, 0.7% minerals (calcium most bioavailable form in any food). Species differences: goat milk (smaller fat globules, easier to digest); sheep milk (6 to 7% fat, 5 to 6% protein); buffalo milk (7 to 8% fat). Quality tests: TPC (below 100,000 cfu/mL Grade A raw milk); SCC (below 200,000 cells/mL; above indicates mastitis); titratable acidity (0.14 to 0.18% lactic acid; higher = bacterial spoilage); alcohol test (milk mixed with 70% ethanol; clotting = too acidic for processing); clot on boiling test (clotting in boiling water = high acidity or colostrum); specific gravity by lactometer (normal 1.027 to 1.033). Adulteration and detection: water addition (most common; lowers specific gravity and fat and protein percentages; detected by lactometer, cryoscopy); fat skimming (cream removed; detected by Gerber fat test; fat below standard 3.5%); starch or flour addition (to restore thickness; detected by iodine test); formalin or hydrogen peroxide addition (to extend shelf life illegally; detected by chemical tests); antibiotic residues (from treated cows; detected by Delvotest or Charm rapid test kits; NAFDAC sets MRLs).
2. Pasteurisation: LTLT (63 degrees Celsius/30 min; small-scale batch operation); HTST (72 degrees Celsius/15 sec; continuous plate heat exchanger; standard industrial method; milk rapidly cooled to below 4 degrees Celsius; aseptically packaged; shelf life 5 to 7 days refrigerated). UHT (135 to 145 degrees Celsius/2 to 6 sec; destroys all pathogens and spores; aseptically packed in laminate cartons; shelf-stable 6 to 12 months at ambient temperature; major brands: Hollandia, Peak, Cowbell). Homogenisation (high-pressure nozzles break fat globules; prevents cream separation). Fermented dairy: yoghurt (pasteurised milk inoculated with S. thermophilus and L. delbrueckii subsp. bulgaricus; 42 to 45 degrees Celsius; 4 to 6

hours; pH 4.2 to 4.4; casein coagulated by lactic acid; set or stirred; stored 0 to 4 degrees Celsius); nono (naturally fermented soured milk; no defined starter; Fulani traditional); wara (Calotropis coagulant; fresh unripened cheese; Middle Belt and north). Butter: cream (35 to 40% fat) separated by centrifuge; churned to rupture fat globule membranes; granules washed, salted, worked into mass; 80% fat, 16 to 18% water; stored 0 to 4 degrees Celsius or frozen. Cheese: milk coagulated by rennet at 30 to 32 degrees Celsius; curd cut, heated, pressed; whey expelled; curd salted and ripened. Dried milk: spray-dried whole or skim milk; 2 to 4% moisture; shelf life 12 to 24 months at ambient temperature.

3. Egg composition: shell (10%; calcium carbonate; 7,000 pores); albumen (58%; 88% water, 11% protein; BV 100, international reference standard; ovalbumin, ovotransferrin, lysozyme); yolk (32%; 33% fat, 17% protein, lecithin, cholesterol 186 mg, vitamins A, D, E, K, B-complex, lutein, zeaxanthin). Yolk colour from dietary xanthophylls; marigold meal or yellow maize deepens colour. Quality assessment: external (shell integrity by candling or acoustic detection; cleanliness; weight); internal (HU = albumen height relative to egg weight; Grade AA above 72; Grade A 60 to 72; Grade B below 60; yolk index 0.40 to 0.42 fresh; air cell small in fresh; blood and meat spots by candling; Roche colour fan for yolk colour). Size grades: extra large above 68 g; large 60 to 68 g; medium 53 to 60 g; small 45 to 53 g; peewee below 45 g. Egg processing: pasteurised liquid egg (break, strain, pasteurise 60 to 64 degrees Celsius for 2 to 4 min, aseptically package as whole egg, white, or yolk; used in bakeries, food manufacturing); dried egg powder (spray-dried; below 5% moisture; shelf life 12 to 24 months); pickled eggs (hard-boiled, peeled, acidified brine below pH 4.6). By-products: blood (4 to 6 L per cattle; spray-dried or drum-dried into blood meal 80 to 85% CP; animal feed); bone (meat and bone meal 50% CP and 30% minerals; gelatin from collagen; bone char for water filtration); feathers (hydrolysed under steam pressure into feather meal 80% CP); hides and skins (300 to 500% value increase from raw to finished leather); tallow and lard (rendered adipose; soap, candles, baking, feed); fishmeal (65 to 70% protein; aquaculture and poultry feed); fish oil (omega-3; aquaculture feed, pharmaceutical supplements). Economic importance: by-products add 10 to 20% to slaughter value; offal adds 15 to 20% to carcass value; Nigeria loses significant by-product value through poor bleeding, hide damage, absence of rendering facilities, and discarding of blood at informal abattoirs; FIIRO and IITA have developed protocols to improve recovery.

Answers to Pilot Questions [Series 4]

Part 4.1

1. Whole cow milk composition: water 87.5% (the continuous phase carrying all other components); fat 3.5% (globules dispersed in water; provides energy and fat-soluble vitamins A, D, E, K); protein 3.3% (primarily casein 80% and whey proteins 20%; casein forms the curd in cheesemaking; whey proteins are heat-sensitive and denatured by pasteurisation; both are of high biological value providing all essential amino acids); lactose 4.8% (the natural milk sugar; fermented by lactic acid bacteria to lactic acid during souring and yoghurt production; 65% of Nigerians have varying degrees of lactose intolerance); minerals and vitamins 0.7% (calcium, phosphorus, magnesium, potassium; B vitamins, vitamin A and D in fat phase; calcium is the most bioavailable dietary calcium source available).
2. Three standard milk quality tests: (1) Total plate count (TPC): a 1 mL sample of milk is diluted and plated on standard plate count agar; incubated at 30 degrees Celsius for 48 to 72 hours; the number of colonies counted and multiplied by dilution factor; acceptable limit for Grade A raw milk destined for pasteurisation is below 100,000 cfu/mL; milk with TPC above 1,000,000 cfu/mL is rejected as unfit for processing. (2) Somatic cell count (SCC): the number of white blood cells (leucocytes) and epithelial cells per millilitre of milk; measured using a direct microscopic somatic cell count or an automated flow cytometer; acceptable limit is below 200,000 cells/mL; counts above 200,000 cells/mL indicate subclinical mastitis in one or more cows in the herd, which reduces milk yield, alters milk composition, and introduces mastitis pathogens (Staphylococcus aureus, Streptococcus agalactiae) into the bulk milk. (3) Titratable acidity: a 10 mL sample of milk is titrated with 0.1 N sodium hydroxide solution using phenolphthalein indicator; the volume of NaOH consumed corresponds to the lactic acid content; fresh milk has titratable acidity of 0.14 to 0.18% lactic acid; values above 0.20% indicate bacterial activity has produced significant lactic acid and the milk is beginning to sour; milk with acidity above 0.22% will fail the alcohol test and is unsuitable for pasteurisation without further processing.
3. Three forms of adulteration and detection: (1) Water addition: the most common form of milk adulteration in Nigeria; water is added to increase volume and profit; detection methods: lactometer (measures specific gravity; normal cow milk 1.027 to 1.033; addition of water dilutes dissolved solids and lowers specific gravity toward 1.000; a reading below 1.026 is suspicious); cryoscopy (measures the freezing point depression of milk; normal cow milk

freezes at minus 0.530 to minus 0.560 degrees Celsius; added water raises the freezing point toward 0 degrees Celsius; the most sensitive and specific test for water addition). (2) Fat skimming: the cream layer is removed by allowing milk to stand or by centrifugation before delivery, reducing fat content while maintaining volume; detection: Gerber or Babcock fat test (dissolves milk protein with sulphuric acid, centrifuges the fat, and reads fat percentage directly from a graduated tube; normal fat 3.5%; below 3.0% with no breed justification suggests skimming). (3) Starch or flour addition: flour, cassava starch, or rice starch is dissolved in water and added to restore the apparent viscosity and whiteness of watered-down milk; detection: iodine test (add a few drops of iodine solution to 5 mL of milk; a blue-black or dark purple colour indicates starch; pure milk turns yellow-brown).

4. Antibiotic residues in milk are a food safety concern for three reasons: (1) Allergic reactions: penicillin and amoxicillin residues in milk cause hypersensitivity reactions in penicillin-allergic consumers; even trace amounts can trigger severe anaphylaxis in sensitised individuals; this is an immediate, potentially life-threatening public health risk. (2) Antimicrobial resistance: repeated low-level antibiotic exposure through contaminated milk selects for antibiotic-resistant bacteria in the human gut microbiome; these resistant bacteria can then cause treatment-resistant infections; the broad use of antibiotics in Nigerian dairy farming, often without veterinary oversight, is a significant AMR risk. (3) Interference with dairy processing: antibiotic residues, even at sub-therapeutic concentrations, inhibit the lactic acid bacteria starter cultures used to manufacture yoghurt, wara, cheese, and nono; antibiotic-contaminated milk fails to ferment normally, resulting in product failures that cause economic loss to processors; this is why dairy plants test incoming milk with rapid antibiotic screening tests (Delvotest, Charm test) before processing.
5. Somatic cell count (SCC) measures the total number of somatic cells (white blood cells called leucocytes plus some epithelial cells shed from the udder lining) per millilitre of milk. What a high SCC indicates: in a healthy udder, leucocytes are present in small numbers as part of the normal immune surveillance of the mammary gland; when the udder is infected by mastitis-causing bacteria (Staphylococcus aureus, Streptococcus uberis, E. coli, Streptococcus agalactiae), the immune system responds by recruiting large numbers of leucocytes to the site of infection; these immune cells enter the milk and cause the SCC to rise; an SCC above 200,000 cells/mL is the internationally accepted threshold for subclinical mastitis (inflammation without visible signs); above 400,000 cells/mL indicates moderate to severe infection. High SCC has three consequences: (1) reduced milk yield from the affected quarter (leucocyte enzymes damage the secretory cells); (2) altered milk composition (lower lactose

and casein, higher sodium and chloride; salty taste; poor cheese yield due to casein degradation by leucocyte proteases); (3) food safety risk (Staphylococcus aureus in mastitic milk can produce heat-stable enterotoxins if milk is held warm).

Part 4.2

1. LTLT and HTST pasteurisation distinguished: LTLT (low temperature long time): milk is heated to exactly 63 degrees Celsius and held at that temperature for 30 minutes in a batch vessel (vat pasteuriser); after holding, the milk is rapidly cooled to below 4 degrees Celsius; the 63 degrees Celsius/30 min combination is the thermal death standard that achieves a 5-log reduction in Coxiella burnetii, the most heat-resistant pathogen of public health significance in raw milk; suitable for small-scale artisanal dairy operations (200 to 2,000 litres per batch) because the equipment is simple and inexpensive; disadvantage: batch production is slow and labour-intensive; heat exposure can produce a slight cooked flavour. HTST (high temperature short time): milk flows continuously through a plate heat exchanger; thin layers of milk flow between stainless steel plates that are alternately heated by hot water (heating section) and cooled by cold water or refrigerant (cooling section); the milk spends exactly 15 seconds in the heating section at 72 degrees Celsius before being cooled; if the temperature sensor detects a drop below 72 degrees Celsius, a flow diversion valve automatically redirects the milk back to the balance tank for reprocessing; suitable for large-scale industrial operations (10,000 to 500,000 litres per day); energy-efficient because the incoming cold raw milk preheats against the outgoing hot pasteurised milk in the regeneration section.
2. UHT processing achieves commercial sterility of liquid milk: all vegetative bacteria, yeast, moulds, and bacterial spores (including the heat-resistant spores of Bacillus subtilis and Clostridium species) are destroyed by exposure to 135 to 145 degrees Celsius for 2 to 6 seconds; this heat treatment is equivalent to a 12-log reduction in the target microorganism and leaves no viable cells or spores capable of growth at ambient temperature. UHT milk does not require refrigeration before opening because: the product is commercially sterile (no viable microorganisms remain to grow and cause spoilage or infection); after heat treatment it is immediately aseptically packed into pre-sterilised multi-layer laminate cartons (Tetra Pak, SIG Combibloc) under sterile conditions; the carton is composed of layers of cardboard, polyethylene, and aluminium foil that provide complete barriers to light, oxygen, and microorganisms; as long as the sealed carton remains intact, no new microbial contamination

can enter and there are no surviving organisms to grow; the shelf life of 6 to 12 months at ambient temperature is therefore achieved purely by the combination of thermal sterilisation and aseptic packaging integrity.

3. Yoghurt production: (1) Milk standardisation: raw milk is standardised to the required fat content (full fat 3.5%, low fat 1.5%, or skim below 0.5%) by adding cream or skim milk as needed; dry milk powder may be added to increase total solids content, which improves gel firmness. (2) Heat treatment: the standardised milk is heated to 85 to 90 degrees Celsius for 15 to 30 minutes; this is higher than pasteurisation and serves two purposes: it destroys all spoilage and pathogenic organisms that would compete with the starter culture, and it denatures whey proteins (beta-lactoglobulin) which improves the viscosity and gel structure of the yoghurt. (3) Cooling: after heat treatment, the milk is cooled to the incubation temperature of 42 to 45 degrees Celsius (the optimum for the yoghurt starter organisms). (4) Inoculation: the cooled milk is inoculated with a defined mixed starter culture of Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus at approximately 2 to 3% inoculum; these two organisms work synergistically: S. thermophilus grows faster initially and produces lactic acid and formate; L. bulgaricus then produces more lactic acid and acetaldehyde (the characteristic yoghurt flavour compound). (5) Incubation at 42 to 45 degrees Celsius for 4 to 6 hours until pH falls to 4.2 to 4.4; the lactic acid produced denatures and precipitates casein forming the characteristic yoghurt gel. (6) Cooling to 0 to 4 degrees Celsius immediately after incubation to arrest further fermentation and preserve the gel structure; stored at this temperature throughout distribution.
4. Butter manufacture from cream: (1) Cream separation: whole milk is centrifuged in a cream separator to produce cream with 35 to 40% fat content; the skimmed milk remaining is used for skim milk products or dried into skim milk powder. (2) Cream pasteurisation and ripening: the cream is pasteurised (72 degrees Celsius/15 sec or 80 degrees Celsius/20 sec) to destroy pathogens; for cultured butter, the pasteurised cream is inoculated with a starter culture (Lactococcus lactis subsp. cremoris) and held at 20 degrees Celsius for 12 to 18 hours to produce diacetyl and lactic acid, which give cultured butter its characteristic flavour; uncultured sweet cream butter is made without this ripening step. (3) Cream tempering: the cream is cooled to 8 to 12 degrees Celsius and held for 8 to 15 hours; this controlled crystallisation of the fat is essential for proper churning; cream that is too warm or too cold does not churn correctly. (4) Churning: the tempered cream is placed in a rotating cylinder (churn) or processed through a continuous butter making machine; agitation causes the fat globule membranes to rupture; the liquid fat that is released coalesces into butter granules

(the fat-continuous phase separates from the buttermilk which is the aqueous phase). (5) Washing, salting, and working: the butter granules are washed with cold water to remove residual buttermilk; salt (up to 2% w/w) is added for flavour and preservation; the granules are worked into a smooth homogeneous mass with 80% fat, 16 to 18% water, and 2 to 4% milk solids non-fat; packed and stored at 0 to 4 degrees Celsius.

5. Spray drying process for milk powder: (1) Milk pre-treatment: raw milk is standardised, pasteurised, and concentrated by evaporation under vacuum (multi-effect evaporation) to 45 to 55% total solids before spray drying; pre-concentration reduces the amount of water that must be removed in the spray dryer, significantly reducing energy consumption. (2) Atomisation: the concentrated milk is pumped at high pressure through a spray nozzle or a rotating atomiser disc at the top of a large cylindrical drying chamber; the liquid is broken into millions of tiny droplets 50 to 200 micrometres in diameter; the large surface area of the droplets allows extremely rapid moisture evaporation. (3) Drying: a stream of hot air (inlet temperature 150 to 220 degrees Celsius) flows through the spray chamber in the same direction as (co-current) or counter to (counter-current) the falling droplets; the evaporation of water from each droplet absorbs so much heat (latent heat of vaporisation) that the droplet surface temperature remains well below the inlet air temperature, protecting heat-sensitive proteins and vitamins from excessive denaturation. (4) Product recovery: the dry powder falls to the bottom of the chamber and is conveyed by air to cyclone separators and bag filters that collect the fine powder; the powder is cooled to prevent caking. Shelf life: whole milk powder (2 to 4% moisture; 2 to 4% fat oxidation risk; shelf life 12 to 18 months in sealed packaging); skim milk powder (2 to 4% moisture; no fat oxidation risk; shelf life up to 24 months); both require sealed, moisture-proof, opaque packaging stored in a cool dry place.

Part 4.3

1. Composition by component and nutritional contribution: Shell (10% of total weight; composed of calcium carbonate 94%, calcium phosphate 1%, magnesium carbonate 1%, and organic matrix 4%; provides a physical barrier against microbial entry through approximately 7,000 pores covered by the cuticle; not nutritionally consumed but the calcium is extractable by vinegar for use as a calcium supplement in some traditional practices). Albumen (58% of total weight; 88% water and 11% protein; contains ovalbumin 54%, ovotransferrin 12%, ovomucin 3.5%, lysozyme 3.4%, and other minor proteins; has the highest biological value of

any food protein at BV 100, the international reference standard; provides all essential amino acids in optimal proportions; ovotransferrin binds iron and inhibits bacterial iron acquisition; lysozyme has mild antibacterial activity; albumen provides essentially no fat and very low caloric density). Yolk (32% of total weight; contains 33% fat, 17% protein, and 48% water; provides all of the fat-soluble vitamins in the egg including retinol (vitamin A), cholecalciferol (vitamin D), tocopherol (vitamin E), and phylloquinone (vitamin K); lecithin (phosphatidylcholine) is the predominant phospholipid and a functional emulsifier; cholesterol approximately 186 mg per yolk; lutein and zeaxanthin carotenoids support macular health; B vitamins including B12, folate, riboflavin, and choline are concentrated in the yolk).

2. The Haugh Unit (HU) is a measure of albumen quality that quantifies the height of the thick albumen dome relative to the weight of the egg; it is calculated using the formula HU = 100 x log(H - 1.7 W^0.37 + 7.57) where H is the height of the thick albumen in millimetres and W is the egg weight in grams. As eggs age or are exposed to heat, the ovomucin protein network in the thick albumen breaks down (through enzymatic proteolysis and CO_2 loss raising pH); the albumen progressively spreads and flattens, reducing the albumen height for a given egg weight; this decline in albumen height is captured by the HU score. HU values for egg grades: Grade AA: HU above 72 (very fresh egg; tall firm albumen dome; egg laid within the past 1 to 2 days); Grade A: HU 60 to 72 (good quality; slightly flatter albumen; acceptable for table egg retail; typical of a 1 to 2 week old egg stored under refrigeration); Grade B: HU below 60 (noticeably flat and watery albumen; egg is older or has been stored at elevated temperature; suitable for industrial processing such as liquid egg manufacture or baking where albumen structure is not critical for the final product).

3. Commercial egg grading classifies eggs by two independent criteria (size and quality) and stamps the grade on the shell or carton for consumer information. Size grading by weight (measured for each individual egg on an automated scale): Extra large (above 68 g per egg; from older hens or larger breeds); Large (60 to 68 g per egg; the standard commercial retail size; most Nigerian commercial layer flocks at peak production lay in this range); Medium (53 to 60 g per egg; common in young layer flocks 18 to 25 weeks of age); Small (45 to 53 g per egg; from young pullets or small breeds); Peewee (below 45 g; usually from very young layers in the first weeks of production; low commercial value). Quality grading by visual inspection, candling, and Haugh Unit measurement: Grade AA (HU above 72; clean uncracked shell; air cell depth below 3 mm by candling; firm yolk well-centred when broken out; no blood or meat spots by candling; suitable for premium fresh retail sale); Grade A (HU

60 to 72; clean uncracked shell; air cell 3 to 6 mm; slightly flat yolk; no blood spots; suitable for standard fresh retail sale); Grade B (HU below 60; slight shell stain permitted; larger air cell; visibly flat or slightly off-centre yolk; small blood or meat spots permitted; downgraded for industrial use in bakeries, liquid egg manufacture, or food service where appearance matters less).

4. Pasteurised liquid egg production: (1) Egg washing and sanitisation: incoming shell eggs are washed in warm water (10 degrees Celsius warmer than the egg to prevent bacterial suction) with a sanitiser solution and rinsed; this removes faecal contamination and reduces surface microbial load before breaking. (2) Breaking: eggs are broken using automated breaking machines at 6,000 to 30,000 eggs per hour; the machines simultaneously separate white and yolk if liquid white or liquid yolk is required, or keep them mixed for whole liquid egg. (3) Straining and filtration: the liquid egg passes through a 500-micrometre screen to remove shell fragments, chalazae (the twisted cord suspending the yolk), and other debris. (4) Pasteurisation: liquid whole egg is pasteurised at 60 to 64 degrees Celsius for 2 to 4 minutes (a gentler condition than milk pasteurisation because egg proteins are more heat-sensitive and denature at lower temperatures, causing product coagulation if temperature is too high); liquid egg white requires even gentler conditions (56 to 57 degrees Celsius for 3 to 4 min) because ovalbumin is particularly heat-sensitive. (5) Aseptic packaging: the pasteurised liquid egg is cooled and aseptically filled into sealed cartons or bags. Applications in Nigeria: bakeries (replacement for shell eggs in cakes, bread, and biscuit manufacture; eliminates shell handling labour and reduces Salmonella risk); confectionery (biscuits, wafers, pastries); fast food chains (standardised omelettes and egg dishes); food manufacturers (mayonnaise, salad dressing, pasta).
5. Yolk colour is determined entirely by the concentration and type of xanthophyll carotenoid pigments in the hen's diet; the hen cannot synthesise carotenoids herself and must absorb them directly from dietary sources. Dietary xanthophylls are deposited unchanged into the developing yolk over the approximately 10 days of follicular growth before ovulation. The primary dietary xanthophyll sources and their effects: yellow maize (contains zeaxanthin and lutein at 20 to 30 mg/kg; produces medium yellow yolks at a Roche colour score of approximately 8 to 10); marigold flower meal (dried Tagetes erecta petals contain lutein and zeaxanthin at very high concentrations, 5 to 15 g/kg; supplemented at 2 to 8 kg per tonne of feed; produces deep yellow to orange yolks at Roche score 12 to 14); white maize and sorghum (contain essentially no xanthophylls; produce pale cream yolks at Roche score 2 to 4); paprika (Capsicum annuum extract rich in capsanthin and capsorubin; produces red-

orange yolks; less commonly used in Nigeria). Commercial importance: Nigerian consumers in the south-west generally prefer deep yellow or orange yolks (Roche score 10 to 13) and associate pale yolks with unhealthy or poor quality eggs, even though yolk colour has no effect on nutritional value or safety; egg producers supplying Lagos supermarkets and fast food chains must use marigold-supplemented diets to achieve the required yolk colour specification; failure to meet the buyer's colour specification results in product rejection.

Part 4.4

1. Blood meal production: blood is collected at slaughter in clean stainless steel or food-grade plastic containers (4 to 6 litres per cattle; 1 to 2 litres per pig); it must be collected hygienically to avoid contamination with rumen contents or faeces. The blood is then processed by one of two methods: spray drying (blood is pumped through an atomiser nozzle into a hot-air chamber at 150 to 220 degrees Celsius inlet temperature; water evaporates instantly from the fine droplets; dry powder falls to the base of the chamber; product is reddish-brown powder with 10% moisture) or drum drying (blood is spread onto the surface of a steam-heated rotating drum at 120 to 150 degrees Celsius; the dried blood is scraped off as flakes). Nutritional value: blood meal contains 80 to 85% crude protein with a high lysine content (7 to 9% of DM); however, the methionine, isoleucine, and threonine content is relatively low; it has a low inclusion rate in feed formulation (typically 2 to 5% of diet) because excessive inclusion reduces palatability due to its strong odour; it is one of the most protein-rich feed ingredients commercially available in Nigeria.
2. Bone processing into meat and bone meal and gelatin: Meat and bone meal: raw bones from the slaughter floor (including vertebrae, rib bones, leg bones, and skull fragments) are first steam sterilised in a pressure vessel (autoclave) at 121 degrees Celsius for 30 minutes to destroy pathogens including prions (the causative agents of BSE); the sterilised material is then dried (either in a steam-jacketed rotary dryer or by forced air) to reduce moisture content below 10%; the dried material is ground and screened to remove large bone fragments; the resulting meal contains approximately 50% crude protein, 30% minerals (primarily calcium phosphate and calcium carbonate), and 8 to 10% fat; it is used as a protein and mineral supplement in poultry, pig, and aquaculture feeds and as a fertiliser. Gelatin: high-collagen bones (skull bones, knuckle bones, vertebrae) are demineralised in dilute acid (to remove calcium phosphate), then boiled in water at 55 to 100 degrees Celsius for several hours; the

collagen triple helix structure is disrupted by heat and the protein dissolves into the water as gelatin; the gelatin solution is filtered, concentrated, and dried to produce sheets or granules; gelatin is used in confectionery (jelly sweets, marshmallow), dairy desserts (panna cotta), pharmaceuticals (capsule shells), and photographic film.

3. Simple drying cannot produce a digestible feather meal because feathers are composed of approximately 90% keratin, a highly stable structural protein with an extensive network of disulphide bonds (cysteine cross-links) between adjacent protein chains. These disulphide bonds make keratin extremely resistant to hydrolysis by digestive proteases; if feathers are simply dried without hydrolysis, the resulting dried feather meal has a crude protein content of 85 to 90% on dry matter basis but a digestibility of only 20 to 40% in monogastric animals because the intact keratin structure is inaccessible to pepsin and pancreatic proteases in the gut. Hydrolysis is required to break these disulphide bonds and open up the keratin structure. The hydrolysis process: cleaned feathers are placed in a pressure cooker or retort vessel with water; steam pressure is applied (typically 1 to 3 bar gauge, corresponding to 120 to 135 degrees Celsius) for 30 to 60 minutes; the heat and pressure break the disulphide bonds and the peptide bonds of the keratin backbone, converting it into shorter polypeptides that are digestible by gastric and pancreatic enzymes in the animal gut; the hydrolysed material is then dried and ground to produce hydrolysed feather meal with approximately 80% crude protein and 75 to 85% digestibility in poultry and pigs.
4. Four animal fat by-products and end uses: (1) Tallow (rendered from cattle and sheep adipose tissue and fatty tissues from the slaughter floor): hardened, white or pale yellow solid fat rich in saturated fatty acids (palmitic, stearic); used in soap manufacturing (saponification with NaOH produces hard soap bars); candle manufacture (high melting point gives firm candles); lubricants; and as an energy ingredient in ruminant and poultry feeds (approximately 9 Mcal/kg metabolisable energy). (2) Lard (rendered from pig adipose tissue, particularly perirenal fat and backfat): softer than tallow; higher proportion of monounsaturated fatty acids (oleic acid); used traditionally in Nigerian baking (pastry shortening, puff-puff); cooking fat; increasingly replaced by vegetable oils but valued for characteristic flavour in traditional baked products. (3) Fishmeal production waste (fish oil from aquatic processing): fish heads, frames, viscera, and trimmings are cooked, pressed to extract fish oil, and the press cake is dried into fishmeal; the fish oil is separated and used in aquaculture feeds as the primary omega-3 fatty acid (EPA and DHA) source for farmed fish; pharmaceutical fish oil capsules (omega-3 supplements) are refined from crude fish oil; in Nigeria, fish oil is a valuable by-product of the catfish and tilapia processing sector. (4) Poultry fat (rendered from

broiler processing waste including skin, abdominal fat, and rendering residues): high in polyunsaturated and monounsaturated fatty acids; used as an energy ingredient in poultry and pig feeds; adds palatability; spray-coated onto finished pellets to improve feed intake.

5. Nigerian abattoirs lose significant economic value from by-products through the following failures: (1) Blood loss: at informal abattoirs, blood is commonly allowed to drain onto the slaughter floor and into drains rather than being collected into vessels; collected blood can be processed into blood meal (80 to 85% crude protein; NGN 800 to 1,200/kg) which would otherwise need to be imported; at 4 to 6 litres of blood per cattle and 100 to 500 cattle per day at a medium state abattoir, the daily blood loss represents several hundred kilograms of blood meal foregone. (2) Hide damage: inadequately trained slaughtermen make knife cuts (scores) through the hide during flaying, each cut reducing the value of the finished leather; knife-scored hides are classified as lower grade and sold at a 30 to 50% discount; with proper training and supervision, a skilled flayman can remove a hide without scores and recover full leather value. (3) Absence of rendering facilities: most Nigerian abattoirs have no rendering plant to process bone, fat trimmings, or condemned material into bone meal or tallow; this material is disposed of as waste or fed to dogs and vultures rather than being converted into animal feed ingredients worth NGN 400 to 800/kg; investment in even a small batch rendering retort would convert this waste into valuable feedstuffs. (4) Offal contamination: if offal is not chilled promptly and handled hygienically after removal from the carcass, it spoils within hours in Nigerian ambient temperatures; spoiled offal cannot be sold and must be discarded; proper chilling and handling would preserve this high-value product (liver fetches NGN 3,000 to 5,000/kg) and extend its marketable life.

References and Attributions [Series 4]

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Figures, Plates, Tables, and Boxes

- Figure 4.1: HTST milk pasteurisation flow diagram Attribution: AI generated. Suggested OER search string: "HTST pasteurisation milk processing flow diagram plate heat exchanger OER".
- Box 4.1: Egg size grades and quality grades with assessment criteria Attribution: AI generated. Suggested OER search string: "egg size grades quality grades Haugh unit air cell AA A B OER box".
- Figure 4.2: Animal by-product utilisation chain diagram Attribution: AI generated. Suggested OER search string: "animal by-product utilisation chain blood bone hide fat tallow gelatin OER diagram".

Course code: AGE 408

Course title: Animal Products Handling, Processing and Storage

Course credit load: 2 Units

Series 5: Marketing, Distribution, and Safety in Animal Products Handling

- **Part 5.1: Marketing of Animal Products in Nigeria**
  - Sub Part 5.1.1: Structure of the Nigerian animal products market
  - Sub Part 5.1.2: Marketing channels and price determination
  - Sub Part 5.1.3: Value chain development and market access
- **Part 5.2: Distribution and the Cold Chain**
  - Sub Part 5.2.1: Cold chain infrastructure and management
  - Sub Part 5.2.2: Packaging for animal products
  - Sub Part 5.2.3: Post-harvest losses and their reduction
- **Part 5.3: Quality Assurance and Certification**
  - Sub Part 5.3.1: Quality management systems
  - Sub Part 5.3.2: Product certification and labelling
  - Sub Part 5.3.3: Export standards and international trade
- **Part 5.4: Challenges and Opportunities in Nigerian Animal Products**
  - Sub Part 5.4.1: Major challenges in the sector
  - Sub Part 5.4.2: Innovations and emerging opportunities
  - Sub Part 5.4.3: Career development and professional practice

Introduction

Producing a safe, high-quality animal product is only the beginning. Getting it to the consumer at the right price, in the right condition, and in compliance with regulations requires effective marketing, distribution, and quality assurance systems. In Nigeria, weaknesses in these systems cause enormous post-harvest losses and limit the competitiveness of the domestic animal products industry.

This final Series covers the structure of Nigerian animal product markets, marketing channels, cold chain management, packaging, post-harvest losses, quality management systems, certification, export standards, the major sector challenges, emerging innovations, and career development opportunities for graduates in animal products technology.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** describe the structure of the Nigerian animal products market and the major marketing channels (Linked to Part 5.1),
- **SLO 5.2** explain how prices are determined and describe strategies for improving market access (Linked to Part 5.1),
- **SLO 5.3** describe cold chain infrastructure, packaging requirements, and post-harvest loss reduction strategies (Linked to Part 5.2),
- **SLO 5.4** describe quality management systems and explain the purpose of product certification and labelling (Linked to Part 5.3),
- **SLO 5.5** describe export standards and explain the requirements for accessing international animal product markets (Linked to Part 5.3),
- **SLO 5.6** identify the major challenges facing the Nigerian animal products sector (Linked to Part 5.4), and
- **SLO 5.7** describe emerging innovations and career opportunities in animal products technology (Linked to Part 5.4).

5.1 Marketing of Animal Products in Nigeria

5.1.1 Structure of the Nigerian animal products market

The Nigerian animal products market is primarily informal. Most meat is sold through live animal markets, abattoir-gate butchers, and open-air market stalls without refrigeration. Most eggs are sold in open trays at roadside kiosks. Milk is largely distributed as UHT cartons in urban supermarkets or as traditionally fermented nono by Fulani traders. The formal chilled and processed meat sector is small but growing, driven by urbanisation and the expansion of supermarkets and fast food chains.

Consumer preferences vary by region and income. Northern Nigerian consumers largely prefer fresh-slaughtered beef and goat from live bird markets, consistent with halal requirements. Southern consumers show higher demand for poultry, fish, and processed products. Middle-class urban consumers in Lagos, Abuja, and Kano are driving growth in branded, certified, and chilled products. Seasonal price peaks occur at Christmas, Eid-el-Adha, Easter, and school resumption periods.

Fill in the blank: The Nigerian animal products market is primarily ________ ; most meat is sold through open-air stalls without refrigeration, but urbanisation and supermarket expansion are growing the formal chilled sector.

5.1.2 Marketing channels and price determination

Major marketing channels: direct farm-to-consumer (farmer sells live animals or fresh products at farm gate); farm to wholesaler to retailer (the most common channel; traders aggregate production and distribute to urban markets); integrated processor to retailer (large companies supply chilled or processed products to supermarkets and fast food chains); and digital platforms (WhatsApp groups, e-commerce sites connecting farmers directly to institutional buyers).

Price determination factors: feed cost (the dominant input cost at 65 to 70% of production cost for poultry); seasonal demand cycles; supply-demand balance in the local market; import competition (cheap frozen chicken and dairy imports depress domestic prices); and transport costs. Processors who add branding, certification, and consistent quality can charge a premium above commodity prices. Forward contracts with institutional buyers stabilise revenue and reduce price risk.

Fill in the blank: Feed constitutes 65 to ________ per cent of poultry production cost; rising feed prices raise production costs and either reduce producer margins or force retail price increases.

5.1.3 Value chain development and market access

A value chain maps all activities from input supply through production, processing, and distribution to the final consumer. Value chain development improves income for all actors by identifying and removing bottlenecks: improving slaughter hygiene increases carcass value; cold chain access extends the market radius; NAFDAC certification opens formal retail; HACCP compliance opens export markets. Cooperatives and producer associations help smallholders pool resources to access markets that are individually inaccessible.

Institutional buyers (schools, hospitals, hotels, military caterers) offer large, stable, long-term contracts to processors who meet hygiene and quality standards. These buyers require NAFDAC registration, consistent supply volume, and formal invoicing. Accessing this segment significantly improves income stability compared with open-market selling. Government programmes including the National Livestock Transformation Plan (NLTP) support value chain development through infrastructure, technical assistance, and market linkage facilitation.

Fill in the blank: The National Livestock Transformation ________ (NLTP) is the federal policy framework supporting value chain development in Nigerian livestock and animal products, including infrastructure investment and market linkage facilitation.

FIGURE 5.1: DIAGRAM OF THE NIGERIAN ANIMAL PRODUCTS VALUE CHAIN FROM INPUT SUPPLY TO CONSUMER

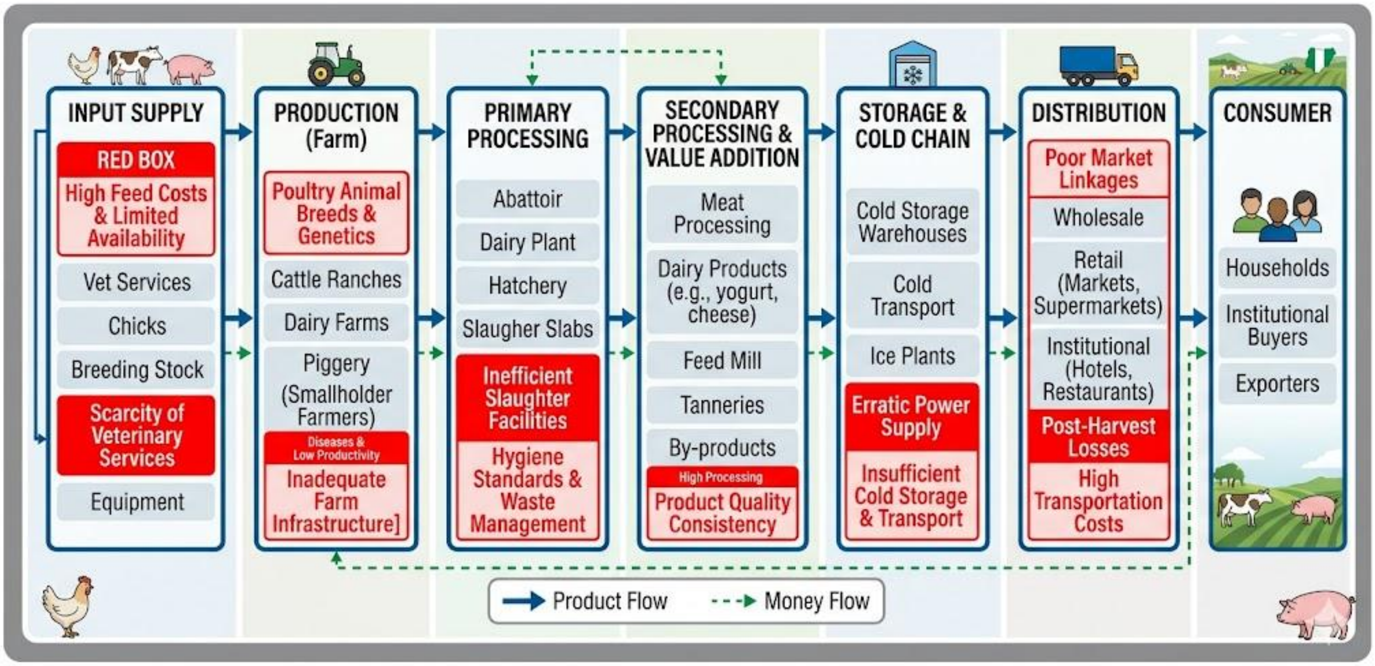

Figure 5.1: Diagram of the Nigerian animal products value chain from input supply to consumer

Pilot questions 5.1

1. Describe the structure of the Nigerian animal products market.
2. State four factors that determine animal product prices in Nigeria.
3. Explain how NAFDAC certification improves market access for a processor.
4. Describe two marketing channels available to a commercial poultry farmer.
5. Explain how forward contracts benefit animal product producers.

5.2 Distribution and the Cold Chain

5.2.1 Cold chain infrastructure and management

The cold chain is the unbroken series of refrigerated storage and transport steps that maintains chilled or frozen products from slaughter or processing to the consumer. In Nigeria, the cold chain is severely underdeveloped: electricity supply is unreliable, refrigerated trucks are scarce, and most retail markets lack cold storage. Cold chain failure causes rapid bacterial multiplication, premature spoilage, and significant economic loss. Improving the cold chain is the single most impactful infrastructure investment for reducing animal product losses.

Cold chain components: pre-cooling (carcass or product chilled to target temperature immediately after processing); refrigerated storage (cold rooms at 0 to 4 degrees Celsius for chilled, minus 18 degrees Celsius for frozen); refrigerated transport (insulated trucks with mechanical refrigeration or isothermal containers with ice); retail cold display (open-fronted chiller cabinets or freezer chests). Each component must be managed and monitored; temperature logs should be kept at each stage and are required for export certification.

Fill in the blank: The cold chain must remain ________ from processing to the consumer; any break in refrigeration causes bacterial growth that cannot be reversed by subsequent chilling.

5.2.2 Packaging for animal products

Packaging functions: containment (holds the product intact during transport and handling); protection (from microbial contamination, oxygen, moisture loss, light, and physical damage); communication (mandatory label information including product name, weight, NAFDAC number, production date, expiry date, batch code, storage conditions, and manufacturer details); and convenience (portion size, resealable, microwaveable). The correct packaging choice significantly extends shelf life and enables formal market access.

Packaging types for animal products: vacuum packaging (removes oxygen; extends chilled beef shelf life from 5 to 7 days to 21 days; used for chilled beef, pork, and poultry portions); modified atmosphere packaging or MAP (replaces air with CO_2-O_2-N_2 mixture; used for fresh retail meat and poultry); Tetra Pak laminate cartons (for UHT milk and liquid egg); polypropylene trays with overwrap (retail poultry and meat); HDPE bottles (pasteurised liquid milk); tinplate cans (corned beef, sardines, tuna). Packaging materials must comply with food-grade safety standards.

Fill in the blank: Vacuum packaging removes ________ from around the meat, extending chilled beef shelf life from 5 to 7 days to approximately 21 days by inhibiting aerobic spoilage bacteria.

5.2.3 Post-harvest losses and their reduction

Post-harvest losses of animal products in Nigeria are estimated at 20 to 40% for meat and up to 60% for raw milk without cooling. Causes: inadequate cold chain; poor slaughter and processing hygiene; rough handling during transport causing bruising and contamination; lack of packaging; and long distances to markets without refrigeration. These losses represent direct economic losses to producers, processors, and traders, and nutritional losses to the population.

Loss reduction strategies: cold chain investment (even basic solar-powered cold storage at abattoir level prevents most bacterial spoilage); improved hygiene training for slaughtermen and handlers; appropriate packaging to prevent contamination and reduce moisture loss; processing of surplus into shelf-stable forms (drying, smoking, canning) rather than selling fresh at a loss; market information systems to match supply with demand and reduce overproduction in peak seasons.

Fill in the blank: Post-harvest losses of raw milk in Nigeria can reach ________ per cent without cooling; investment in even basic on-farm chilling reduces this dramatically by preventing rapid bacterial multiplication.

Product	**Losses (%)**	**Causes**	**Reduction Strategies**
Beef	20–30%	No cold chain, bruising, poor market hygiene	Abattoir chilling, refrigerated transport, MAP packaging
Raw Milk	Up to 60%	No farm cooling, long distances to dairy plant	On-farm milk chiller, collection centre cooling, pasteurisation, UHT processing
Poultry	15–25%	No refrigeration at market, poor hygiene	Chilled retail, packaging, local processing into value-added products
Eggs	10–20%	Breakage, poor storage, heat exposure	Padded trays, collection twice daily, refrigerated storage
Fish	30–50%	No ice, delays in handling	On-boat icing, landing site ice plants, smoking, drying

Box 5.1: Summary of post-harvest losses and reduction strategies for key animal products in Nigeria

Pilot questions 5.2

1. Explain what the cold chain is and why it is critical for animal product safety.
2. State four components of a cold chain for chilled meat distribution.
3. Name three types of packaging used for animal products and state the function of each.
4. State three causes of post-harvest losses in Nigerian animal products.
5. Describe two strategies for reducing post-harvest losses of raw milk in Nigeria.

5.3 Quality Assurance and Certification

5.3.1 Quality management systems

A quality management system (QMS) is a documented set of policies, procedures, and processes that ensure products consistently meet defined quality and safety standards. In animal product processing, the hierarchy of QMS is: GMP (Good Manufacturing Practice) at the foundation, followed by HACCP, and then ISO 22000 (food safety management system integrating GMP, HACCP, and additional management system requirements). NAFDAC requires GMP and HACCP as minimum standards for product registration.

Total Quality Management (TQM) is a broader philosophy that involves all employees in continuous improvement of product quality and process efficiency. Key tools: statistical process control (monitoring process parameters to detect deviations before they cause defects); internal audit (systematic inspection of all processes against documented procedures); corrective and preventive action (CAPA) systems; and management review of quality performance data. These systems collectively reduce product failures, recalls, and waste.

Fill in the blank: The hierarchy of food safety management systems is GMP at the foundation, followed by HACCP, and then ISO ________ (food safety management system) for full international certification.

5.3.2 Product certification and labelling

NAFDAC registration: all commercially processed animal products in Nigeria must carry a NAFDAC registration number on the label. The manufacturer submits product composition, processing method, and safety test data; a facility inspection for GMP compliance is conducted; on approval a unique registration number is issued. Products without a NAFDAC number cannot be legally sold in Nigerian markets and may be seized and destroyed.

Halal certification: issued by approved Islamic bodies (e.g. the Halal Certification Board of Nigeria) confirming that meat products meet Islamic slaughter and processing requirements; required by Muslim consumers and for export to Muslim-majority countries. SON certification mark (the Standards Mark): awarded when a product consistently meets the relevant Nigerian Industrial Standard; provides consumer assurance and is required for some government procurement. Product labelling must state: product name, net weight, NAFDAC number, manufacturing date, best before date, storage conditions, manufacturer name and address, and ingredient list.

Fill in the blank: All commercially processed animal products in Nigeria must carry a NAFDAC ________ number on the label; products without this number cannot be legally sold in Nigerian markets.

5.3.3 Export standards and international trade

Exporting Nigerian animal products to the EU, USA, Middle East, or other formal markets requires compliance with the importing country's standards, which are typically more stringent than domestic Nigerian standards. EU requirements for meat imports: the exporting country's competent authority must be on the EU approved third country list; the processing establishment must be individually listed; residue monitoring plans (for antibiotics, pesticides, and heavy metals) must be in place and submitted to the EU annually; HACCP must be documented and verified.

Nigerian animal products currently exported include: hides and skins (Kano leather to Europe); dried crayfish and smoked fish (to the West African diaspora in the UK and US); and some live animals and chilled goat meat to the Middle East. Nigeria has historically struggled to access premium export markets for fresh meat and dairy because of inadequate veterinary certification systems, residue monitoring, and cold chain infrastructure. Strengthening these systems is a priority of the NLTP.

Fill in the blank: Nigerian animal product processors seeking EU export certification must have documented HACCP, a national ________ monitoring plan for antibiotics and pesticides, and approval of the processing establishment by the EU.

Figure 5.2: Diagram showing the requirements for Nigerian animal product export certification

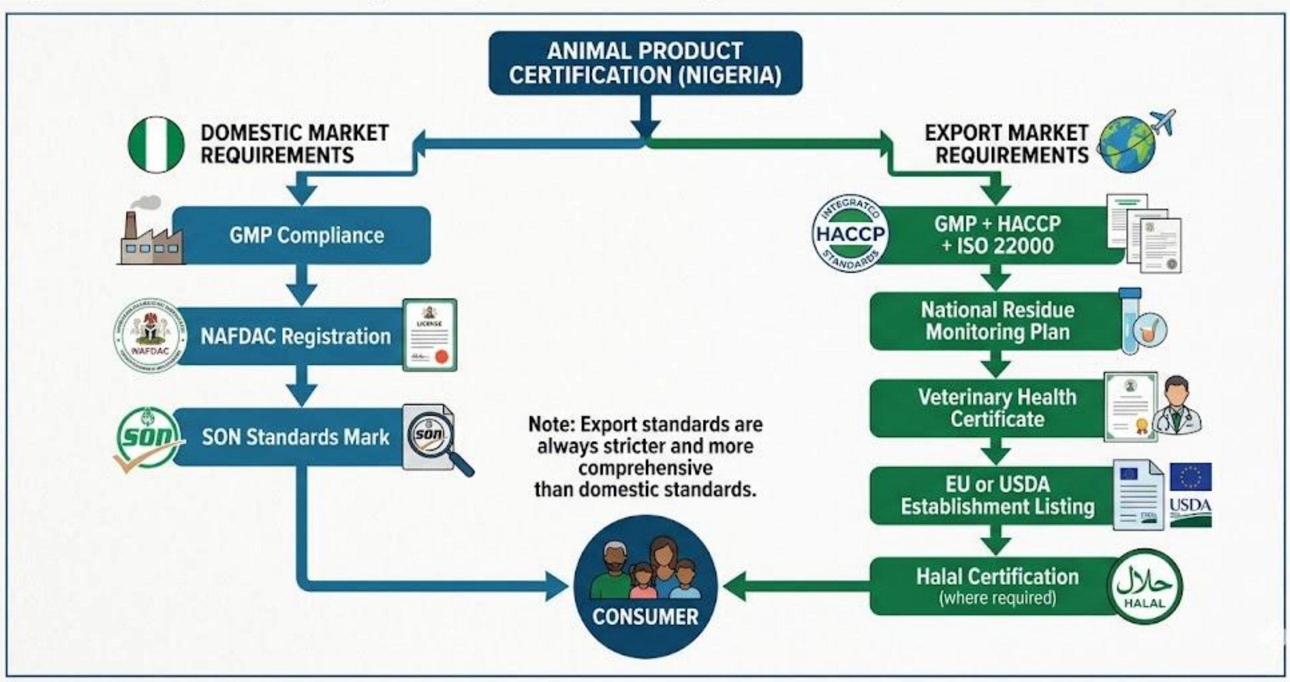

Figure 5.2: Diagram showing the requirements for Nigerian animal product export certification

Pilot questions 5.3

1. Describe the hierarchy of quality management systems from GMP to ISO 22000.
2. Explain the purpose and process of NAFDAC product registration.
3. State the labelling information required on a commercially sold animal product in Nigeria.
4. Explain what halal certification is and why it matters for animal product marketing.
5. State three requirements for exporting Nigerian meat products to the EU.

5.4 Challenges and Opportunities in Nigerian Animal Products

5.4.1 Major challenges in the sector

Feed cost: feed constitutes 65 to 70% of production cost for poultry and pig operations; volatile maize and soyabean prices, driven by import dependence and forex fluctuation, are the leading cause of production cost instability. Disease burden: Newcastle disease, avian influenza, foot and mouth disease, and mastitis cause direct production losses and trigger trade bans that restrict access to export markets.

Cold chain deficit: Nigeria has an estimated cold chain capacity of less than 10% of what is required to handle the volume of perishable animal products produced annually; this deficit forces live animal marketing, limits the market radius of fresh products, and causes enormous post-harvest losses. Other challenges: inadequate veterinary and food safety inspection capacity at abattoirs and markets; illegal importation of cheap frozen poultry and dairy products undermining domestic prices; limited access to affordable credit for processing infrastructure investment.

Fill in the blank: Nigeria has an estimated cold chain capacity of less than ________ per cent of what is needed; this forces live animal marketing and causes the majority of animal product post-harvest losses.

5.4.2 Innovations and emerging opportunities

Alternative feed ingredients: black soldier fly (Hermetia illucens) larvae meal contains 40 to 45% crude protein and can partially replace soyabean and fishmeal, reducing feed cost; Nigerian research institutions (IITA, FIIRO) are developing protocols for commercial-scale production. Agri-tech platforms: digital livestock management applications, e-commerce for farm produce, online abattoir booking and scheduling, and drone-based surveillance of large ranches are emerging in Nigeria.

Solar-powered cold storage: small solar cold rooms (10 to 30 m3) are increasingly affordable and can operate without grid electricity, enabling abattoir-level and farm-level chilling in rural areas;

several Nigerian start-ups (Thrive Agric, ColdHubs) are deploying these. Value addition opportunities: growing urban middle class and expanding food service sector create demand for branded packaged meat, UHT dairy, processed poultry products, and convenience egg products; these segments offer 2 to 5 times the farm-gate price per unit of raw commodity.

Fill in the blank: Black soldier fly larvae meal contains ________ to 45 per cent crude protein and can partially replace costly soyabean meal and fishmeal in poultry and fish feeds, reducing production costs.

5.4.3 Career development and professional practice

Graduates in animal products technology are equipped for diverse career paths: government inspection (NAFDAC product evaluation officer, state ministry meat inspector, veterinary public health officer); private sector quality assurance (QA manager in a meat processing plant, dairy, or poultry processor; cold chain operations manager; product development technologist); research and academia (FIIRO food scientist, university lecturer, IITA value chain researcher); and entrepreneurship (establishing an abattoir, dairy, smoked fish business, or egg grading centre).

Professional development: registration with the Nigerian Institute of Animal Science (NIAS) provides professional recognition and access to continuing education; membership in the Council for the Regulation of Engineering in Nigeria (COREN) is relevant for food engineers; NAFDAC and SON run certified food safety auditor training programmes. Continuous professional development through short courses, industry attachments, and international certification (HACCP auditor, ISO 22000 lead auditor, food safety manager) significantly enhances employability and career progression.

Fill in the blank: The Nigerian Institute of Animal ________ (NIAS) provides professional registration and continuing education for graduates in animal science and animal products technology.

Sector	Roles	Professional Bodies

Government	NAFDAC evaluation officer; state ministry meat inspector; veterinary public health officer; SON quality auditor	Linked to regulatory agencies
Private Sector	QA manager (meat, dairy, poultry); cold chain manager; product development technologist; food safety consultant	Industry associations and HACCP auditors
Research	FIIRO food scientist; IITA value chain researcher; university lecturer	Academic and research institutions
Entrepreneurship	Abattoir operator; dairy processor; smoked fish enterprise; egg grading centre; hide and skin tannery	SME networks and cooperatives
Professional Bodies	NIAS (Nigerian Institute of Animal Science); COREN (food engineers); registered HACCP auditor; ISO 22000 lead auditor	Provides certification, standards, and recognition

Box 5.2: Career pathways and relevant professional bodies for animal products technology graduates

Pilot questions 5.4

1. State three major challenges facing the Nigerian animal products sector.
2. Explain how solar cold storage addresses the cold chain deficit in Nigeria.
3. Describe two emerging innovations that could improve the Nigerian animal products sector.
4. Name four career options for a graduate in animal products technology.
5. Explain the value of HACCP auditor certification for a career in animal products.

Series Summary

This final Series covered marketing, distribution, and safety. The Nigerian animal products market is predominantly informal; formal chilled and processed products are growing with urbanisation. Price is determined by feed cost, seasonal demand, import competition, and transport costs. Marketing channels include farm-gate, wholesale, integrated processor-to-retailer, and digital platforms. The cold chain is underdeveloped; breaks cause rapid spoilage and major post-harvest losses (meat 20 to 40%; raw milk up to 60%).

Packaging types (vacuum, MAP, Tetra Pak, polypropylene trays, cans) extend shelf life and enable market access. QMS hierarchy: GMP then HACCP then ISO 22000; NAFDAC registration and SON certification are required for formal markets; halal certification is required for Muslim markets and export. EU export requires documented HACCP, residue monitoring, and establishment listing. Challenges: feed cost, disease, cold chain deficit, inadequate inspection, illegal imports. Opportunities: alternative feeds, agri-tech, solar cold storage, value addition to growing urban markets. Career paths span government, industry, research, and entrepreneurship. By completing this Series, you should achieve all seven SLOs (5.1 to 5.7) and all course outcomes.

Glossary of Terms

- **Agri-tech:** digital and technology-based innovations applied to agriculture and animal products; includes e-commerce platforms, livestock management apps, and drone surveillance.
- **Black soldier fly (BSF):** Hermetia illucens; an insect whose larvae provide 40 to 45% crude protein; a sustainable alternative protein source for poultry and aquaculture feeds.
- **Cold chain:** the unbroken series of refrigerated storage and transport steps that maintains chilled or frozen products from processing to the consumer.
- **ColdHubs:** a Nigerian cold storage company providing solar-powered walk-in cold rooms on a pay-per-use basis to smallholder farmers and traders in rural areas.

- **Corrective and preventive action (CAPA):** a quality management tool for identifying the root cause of a defect or near-miss and implementing actions to prevent recurrence.
- **Forward contract:** a pre-agreed sale of a specified quantity and quality of animal product at a fixed price for future delivery; reduces price risk for the producer.
- **GMP (Good Manufacturing Practice):** the documented operational foundation covering premises, equipment, personnel, and process control; the prerequisite programme for HACCP.
- **HACCP:** Hazard Analysis and Critical Control Points; the systematic food safety management system identifying and controlling biological, chemical, and physical hazards at critical points.
- **Halal certification:** formal certification by an approved Islamic body confirming that a food product meets Islamic dietary law requirements for slaughter and processing.
- **ISO 22000:** an international standard for food safety management systems; integrates GMP, HACCP, and broader management system requirements; required for formal export market certification.
- **MAP (modified atmosphere packaging):** packaging where air is replaced with a controlled gas mixture (CO_2, O_2, N_2) to inhibit aerobic spoilage bacteria and extend shelf life.
- **NAFDAC:** National Agency for Food and Drug Administration and Control; registers all commercial food products and enforces food safety and quality standards in Nigeria.
- **NIAS:** Nigerian Institute of Animal Science; the professional body providing registration and continuing education for animal scientists and animal products technology graduates.
- **NLTP:** National Livestock Transformation Plan; the federal policy framework for developing the Nigerian livestock and animal products sector.
- **Post-harvest loss:** the reduction in quantity or quality of a food product between production and consumption; for animal products in Nigeria, estimated at 20 to 60% depending on species and product.
- **SON (Standards Organisation of Nigeria):** sets Nigerian Industrial Standards (NIS) for product quality; awards the SON Standards Mark to conforming products.
- **Solar cold room:** a walk-in cold storage room powered by photovoltaic panels; eliminates dependence on grid electricity; increasingly affordable for rural Nigerian abattoirs and farms.

- **Statistical process control:** a quality tool using statistical methods to monitor process parameters (temperature, pH, weight) and detect deviations before they cause product defects.
- **Total Quality Management (TQM):** a company-wide philosophy of continuous improvement involving all employees in achieving consistent product quality and customer satisfaction.
- **Value chain:** all linked activities from input supply through production, processing, distribution, and retail to the final consumer; analysis identifies bottlenecks that reduce product value.
- **Vacuum packaging:** packaging in which air is evacuated before sealing; removes oxygen, inhibiting aerobic spoilage bacteria; extends chilled beef shelf life from 5 to 7 days to 21 days.

Concept Check Questions [Series 5]

Objective Questions

1. The Nigerian animal products market is primarily ________ ; most meat is sold through open-air stalls without refrigeration. (Linked to SLO 5.1)
2. Feed constitutes 65 to ________ per cent of poultry production cost; rising feed prices raise production costs and reduce producer margins. (Linked to SLO 5.2)
3. The cold chain must remain ________ from processing to the consumer; any break causes bacterial growth that cannot be reversed by subsequent chilling. (Linked to SLO 5.3)
4. All commercially processed animal products in Nigeria must carry a NAFDAC ________ number on the label before they can be legally sold. (Linked to SLO 5.4)
5. Black soldier fly larvae meal contains ________ to 45 per cent crude protein and can partially replace soyabean meal in poultry and fish feeds. (Linked to SLO 5.7)

Short-Answer Questions

11. State four factors that determine animal product prices in Nigeria. (Linked to SLO 5.2)
12. State four components of a cold chain for chilled meat distribution. (Linked to SLO 5.3)
13. Explain the hierarchy of quality management systems from GMP to ISO 22000. (Linked to SLO 5.4)

14. State three requirements for exporting Nigerian meat products to the EU. (Linked to SLO 5.5)
15. State three major challenges facing the Nigerian animal products sector. (Linked to SLO 5.6)

Long-Answer Questions

1. Describe the structure of the Nigerian animal products market, the major marketing channels, and strategies for improving value chain development and market access. (Linked to SLOs 5.1, 5.2)
2. Describe cold chain infrastructure, packaging types, and post-harvest loss reduction strategies for animal products in Nigeria. (Linked to SLO 5.3)
3. Describe quality management systems, product certification and labelling requirements, export standards, and the major challenges and opportunities facing the Nigerian animal products sector. (Linked to SLOs 5.4, 5.5, 5.6, 5.7)

Answers to Concept Check Questions [Series 5]

Objective Questions

1. Informal.
2. 70.
3. Unbroken.
4. Registration.
5. 40.

Short-Answer Questions

1. Feed cost (65 to 70% of poultry production cost); seasonal demand (price peaks at Christmas, Eid, Easter); supply-demand balance in local markets; and import competition from cheap frozen poultry and dairy.

2. Pre-cooling (chill product immediately after processing); refrigerated cold room storage (0 to 4 degrees Celsius chilled, minus 18 degrees Celsius frozen); refrigerated transport (insulated trucks or isothermal containers with ice); and retail cold display (chiller cabinets or freezer chests).
3. GMP is the prerequisite foundation covering premises, equipment, personnel, and process hygiene. HACCP builds on GMP by identifying specific food safety hazards and Critical Control Points. ISO 22000 integrates GMP, HACCP, and broader management system requirements for full international certification.
4. Documented HACCP system; national residue monitoring plan for antibiotics and pesticides; and individual processing establishment listing by the EU competent authority.
5. High feed cost (65 to 70% of production cost; volatile prices); cold chain deficit (less than 10% of required capacity; causes major post-harvest losses); and illegal imports of cheap frozen poultry and dairy that undercut domestic prices.

Long-Answer Questions

1. Market structure: predominantly informal; most meat sold through open-air stalls without refrigeration; eggs in open trays at kiosks; milk as UHT in urban supermarkets or nono by Fulani traders; formal chilled sector growing with urbanisation and supermarket expansion. Regional preferences: north (fresh-slaughtered halal beef and goat); south (poultry, fish, processed products); urban middle class (branded, certified, chilled products). Price peaks at festive periods. Marketing channels: farm-gate direct sale; farm-wholesale-retailer (most common); integrated processor-to-supermarket/fast food; digital platforms (WhatsApp, e-commerce). Price determinants: feed cost; seasonal demand; supply-demand balance; import competition; transport costs. Value chain development: GMP and NAFDAC certification open formal retail; HACCP compliance opens institutional buyers and export; cooperatives give smallholders collective market access; NLTP provides infrastructure and market linkage support.
2. Cold chain: the unbroken series of refrigerated steps from processing to consumer; Nigeria has less than 10% of required cold chain capacity; unreliable electricity and scarce refrigerated trucks are the main constraints. Components: pre-cooling (immediate chilling at abattoir or dairy); cold room storage (0 to 4 degrees Celsius for chilled; minus 18 for frozen); refrigerated transport; retail cold display; temperature logs required for export. Packaging:

vacuum packaging (removes oxygen; extends beef shelf life to 21 days); MAP (CO2-O2-N2 mixture; fresh retail meat and poultry); Tetra Pak laminate cartons (UHT milk, liquid egg); polypropylene trays with overwrap (retail poultry and meat); tinplate cans (corned beef, sardines). Post-harvest losses: meat 20 to 40%; raw milk up to 60% without cooling. Causes: no cold chain; poor hygiene; rough transport; no packaging; long distances to market without refrigeration. Reduction strategies: solar cold rooms at abattoir level; hygiene training for handlers; appropriate packaging; processing surplus into dried or smoked shelf-stable products.

3. QMS hierarchy: GMP (prerequisite; premises, equipment, personnel, process); HACCP (hazard analysis, CCPs, critical limits, monitoring, corrective action, records, verification); ISO 22000 (integrates GMP and HACCP with broader management system requirements; required for formal export). NAFDAC registration: submit product composition, processing method, and safety test data; facility inspection for GMP; approved products receive NAFDAC number on label; illegal to sell without it. Labelling requirements: product name, net weight, NAFDAC number, manufacturing date, best before date, storage conditions, manufacturer name and address, ingredient list. Halal certification: from approved Islamic body; confirms slaughter and processing meet Islamic dietary law; required for Muslim consumers and export to Muslim-majority countries. SON Standards Mark: confirms product meets NIS quality standards; required for some government procurement. Export to EU: documented HACCP; national residue monitoring plan for antibiotics and pesticides; EU establishment listing; veterinary health certificate. Challenges: feed cost volatility; disease burden (ND, AI, FMD); cold chain deficit under 10% of need; inadequate inspection capacity at abattoirs; illegal imports depressing prices; limited affordable credit. Opportunities: black soldier fly larvae meal (40 to 45% CP; reduces feed cost); solar cold storage (grid-independent; rural deployment by ColdHubs and start-ups); agri-tech platforms (e-commerce, farm management apps); value addition to urban consumer products (2 to 5 times farm-gate price). Careers: NAFDAC officer; state meat inspector; QA manager in meat, dairy, or poultry processing; cold chain manager; FIIRO researcher; university lecturer; abattoir or dairy entrepreneur; HACCP or ISO 22000 auditor.

Answers to Pilot Questions [Series 5]

Part 5.1

1. The market is predominantly informal; most meat is sold at open-air abattoir-gate butchers and market stalls without refrigeration; most eggs are sold in open trays at kiosks; milk is distributed as UHT in urban supermarkets or as nono by Fulani traders; the formal chilled and processed sector is small but growing with urbanisation and supermarket expansion.
2. Feed cost (65 to 70% of poultry production cost; the most important single determinant); seasonal demand (prices spike at festive periods); supply-demand balance in local markets (excess supply causes price collapses); illegal import competition (cheap frozen poultry and dairy depress domestic prices).
3. NAFDAC registration gives a processor a NAFDAC number on the label, which is legally required for sale in all Nigerian formal retail outlets; without it, supermarkets, hotels, schools, and hospitals cannot legally purchase the product; certification also signals to buyers that GMP and safety standards have been verified by a federal authority, building consumer trust and justifying a premium price.
4. Two channels: (1) Farm-gate direct sale, where the farmer sells live birds or chilled carcasses directly to local buyers, traders, or consumers at the farm; this requires no intermediary but limits market reach to buyers who can visit the farm. (2) Integrated processor-to-retailer channel, where the farmer produces birds and delivers to a licensed processing plant that chills, packages, and distributes the product to supermarkets and fast food chains under a supply contract; this channel commands higher prices but requires consistent quality and volume.
5. A forward contract fixes the sale price, quantity, and quality before the production cycle begins; this eliminates the price uncertainty the producer faces at harvest, when prices may have collapsed due to seasonal oversupply; it also guarantees a buyer, removing the risk of being unable to sell the product; in return, the producer must deliver the agreed specification on the agreed date.

Part 5.2

1. The cold chain is the unbroken series of refrigerated storage and transport steps from processing to the consumer; it is critical because chilled meat, milk, and eggs support rapid bacterial growth above 4 degrees Celsius; any break (a warm delivery truck, an unrefrigerated market stall) allows bacteria to multiply to unsafe levels; once contaminated, subsequent chilling does not remove toxins already produced.
2. Four cold chain components for chilled meat: (1) pre-cooling (carcass chilled to below 7 degrees Celsius immediately at the abattoir before dispatch); (2) refrigerated cold room storage (0 to 4 degrees Celsius; holds chilled meat between production and dispatch); (3) refrigerated transport (insulated truck with mechanical refrigeration or isothermal containers packed with ice); (4) retail cold display (open-fronted chiller cabinet maintaining 0 to 4 degrees Celsius at point of sale).
3. Three packaging types: (1) vacuum packaging (evacuates air before sealing; removes oxygen; extends chilled beef shelf life from 5 to 7 days to 21 days; used for portions and primals); (2) modified atmosphere packaging MAP (replaces air with a controlled CO_2-O_2-N_2 mix; inhibits spoilage bacteria; maintains bright red meat colour for retail display); (3) Tetra Pak laminate carton (paperboard-polyethylene-aluminium foil laminate; provides complete barrier to oxygen and microorganisms; used for UHT milk and aseptic liquid egg; shelf-stable for 6 to 12 months).
4. Three causes: inadequate cold chain (no refrigerated storage or transport means products spoil rapidly at ambient temperature); poor slaughter and processing hygiene (high initial bacterial load on the product accelerates spoilage even if cooling is eventually applied); and long distances to markets without refrigeration (fresh products deteriorate during multi-hour road journeys in unrefrigerated vehicles in hot Nigerian conditions).
5. Two strategies: (1) On-farm or abattoir-level milk chiller (a stainless steel cooling tank that chills freshly collected milk to below 4 degrees Celsius within 2 hours of milking; this reduces bacterial doubling from once every 20 to 30 minutes at ambient temperature to once every 10 to 12 hours; solar-powered units are available for grid-independent operation). (2) Pasteurisation at a nearby collection centre or dairy plant (HTST pasteurisation at 72 degrees Celsius for 15 seconds destroys all vegetative pathogens and dramatically extends shelf life from 2 to 3 days raw to 5 to 7 days pasteurised; even small-scale community pasteurisers can serve multiple farms in a catchment area).

Part 5.3

1. GMP is the prerequisite foundation covering premises, equipment, personnel hygiene, raw material control, and process hygiene documentation; it creates the basic hygienic conditions without which no food safety system can function. HACCP builds on GMP by systematically identifying biological, chemical, and physical food safety hazards and establishing Critical Control Points where control measures are applied. ISO 22000 integrates GMP and HACCP with additional management system requirements including management commitment, internal audit, and continuous improvement; it is the standard required for formal international export market access.
2. NAFDAC registration requires the manufacturer to submit: a detailed product formulation (all ingredients and their concentrations); a description of the manufacturing process including pasteurisation or heat treatment conditions; laboratory test results confirming microbiological safety (TPC, coliform, Salmonella absence), chemical composition (fat, protein, moisture), and absence of veterinary drug residues above MRLs; a sample of the finished product label for review; and a facility inspection report. NAFDAC inspectors then visit the facility to verify GMP compliance in practice. On approval, the product receives a unique NAFDAC registration number (e.g. NAFDAC REG. NO. LD-12345A) that must appear on every label; this number is also entered into the NAFDAC product database which consumers and enforcement officers can verify.
3. Required labelling information: product name (common name of the food); net weight or volume; NAFDAC registration number; manufacturing date (date on which the product was produced); best before or expiry date (the date after which the product should not be consumed); storage conditions (e.g. "keep refrigerated at 0 to 4 degrees Celsius" or "store in a cool dry place"); manufacturer name, brand, and full address (including state and country); complete ingredient list in descending order of weight; and country of origin for imported products.
4. Halal certification is formal confirmation by an approved Islamic body that a food product has been produced in compliance with Islamic dietary law (Sharia): the animal was alive and healthy at slaughter, a Muslim slaughterman performed the slaughter with Bismillah recitation, the throat was cut severing the carotid arteries and jugular veins, the animal was completely bled, and no pork or alcohol was used in processing or packaging. It matters commercially because: (1) the majority of Nigerian consumers are Muslim and require halal assurance for all meat products; (2) export to Middle Eastern and South-East Asian markets

(where import regulations mandate halal certification) is impossible without it; (3) it provides consumer confidence that commands a market premium in competitive urban retail segments.

5. Three requirements: (1) Documented HACCP system covering all stages from raw material receipt through processing to finished product dispatch, with records of monitoring, corrective actions, and verification activities that can be presented to EU auditors on request. (2) National residue monitoring plan submitted annually to the EU, demonstrating that Nigeria systematically samples and tests animal products from farms and processing plants for antibiotic residues, pesticide residues, and heavy metals at levels consistent with EU maximum residue limits. (3) Individual processing establishment listing on the EU's approved establishment register, which requires the Nigerian competent authority (Federal Ministry of Agriculture) to inspect and certify the specific plant against EU structural and hygiene standards and formally recommend it to the EU for listing.

Part 5.4

1. Three challenges: (1) Feed cost volatility (maize and soyabean together constitute 65 to 70% of poultry production cost; domestic prices fluctuate with currency devaluation, import restrictions, and seasonal availability; a 30% rise in maize price increases total production cost by approximately 20%, eliminating profit margins at fixed retail prices). (2) Cold chain deficit (Nigeria has less than 10% of the cold chain capacity needed for its volume of perishable animal products; this forces live animal marketing, restricts the market radius of fresh products, and causes 20 to 60% post-harvest losses depending on the product). (3) Disease burden (Newcastle disease remains endemic in village flocks that serve as permanent reservoirs infecting commercial farms; avian influenza outbreaks trigger trade bans; foot and mouth disease in cattle restricts export; mastitis reduces dairy yield and milk quality; disease control requires coordinated national veterinary effort that exceeds current capacity).
2. Solar cold rooms are pre-fabricated insulated walk-in cold storage rooms (typically 10 to 30 cubic metres) powered entirely by rooftop photovoltaic panels with battery backup; they operate at 0 to 4 degrees Celsius for chilled products or minus 10 to minus 20 degrees Celsius for frozen products without any grid electricity connection. They address the cold chain deficit in Nigeria by: (1) eliminating dependence on the unreliable national electricity grid (which averages 4 to 8 hours per day in most states), making them viable in any rural location with adequate solar irradiation; (2) reducing operating costs compared with diesel generator-

powered cold rooms by eliminating fuel cost; (3) being deployable at abattoir level, farm level, or collection centre level on a pay-per-use business model (the ColdHubs model charges farmers per crate per day), making them accessible to smallholders without large capital investment.

3. Two innovations: (1) Black soldier fly (BSF) larvae meal as an alternative feed ingredient: Hermetia illucens larvae are reared on organic waste streams (food waste, brewery waste, cassava peels) and harvested at peak protein content (40 to 45% crude protein, 30 to 35% fat on dry matter basis); the larvae meal can replace up to 30 to 50% of soyabean meal and fishmeal in poultry and catfish diets with equivalent performance; Nigerian research (IITA, University of Ibadan, FIIRO) has validated its safety and digestibility in local conditions; commercial-scale BSF facilities are now operating in Lagos and Ogun states, with feed cost reductions of 10 to 20% reported. (2) Digital agri-tech platforms for direct market linkages: smartphone and feature phone applications allow farmers to list available animals and products, receive price information from multiple markets simultaneously, book slaughter slots at registered abattoirs, and arrange pickup by verified buyers; these platforms reduce market information asymmetry (where traders historically knew prices from multiple markets while farmers knew only local prices), giving farmers negotiating power; examples include Farmcrowdy (now CrowdFarm), ThriveAgric, and various WhatsApp-based farmer cooperative trading networks.
4. Four career options: (1) NAFDAC product evaluation officer or food safety inspector (government; inspects facilities, reviews product registration dossiers, conducts market surveillance, enforces recalls of unsafe products); (2) quality assurance manager in a meat processing plant, dairy, or poultry processor (private sector; manages GMP and HACCP implementation, internal audit, supplier qualification, product testing, and regulatory compliance); (3) food scientist at FIIRO or a university department of animal science (research; develops and tests new processing technologies and by-product utilisation protocols; conducts value chain research); (4) entrepreneur owning and operating a value-added animal products enterprise (small-scale abattoir with a chilled retail unit; dairy processing unit producing yoghurt and wara; smoked fish business with solar dryer; egg grading and packing centre supplying supermarkets).
5. HACCP auditor certification qualifies a professional to conduct systematic audits of HACCP plans in food processing facilities against internationally recognised standards (Codex Alimentarius HACCP guidelines, ISO 22000, FSSC 22000). Its career value: (1) it is required for employment as a third-party food safety auditor for certification bodies (SGS, Bureau

Veritas, Intertek) that certify Nigerian food processors against ISO 22000 or FSSC 22000; (2) NAFDAC and major Nigerian food companies (Chi Group, Promasidor, Honeywell Flour Mills) require their QA managers to hold HACCP or food safety management certification; (3) it enables consultancy work advising small and medium-sized processors on implementing HACCP systems for NAFDAC registration; (4) it is a prerequisite for working on export market compliance projects where EU or USDA-compliant HACCP documentation must be prepared and maintained.

References and Attributions [Series 5]

Textual References (Books and External Sources)

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- Codex Alimentarius Commission. (2020). General principles of food hygiene (CXC 1-1969, Rev. 2020). FAO/WHO.
- Aberle, E. D., Forrest, J. C., Gerrard, D. E., & Mills, E. W. (2001). Principles of meat science (4th ed.). Kendall Hunt.

Figures, Plates, Tables, and Boxes

- Figure 5.1: Nigerian animal products value chain diagram Attribution: AI generated. Suggested OER search string: "Nigerian animal products value chain diagram input supply farm processing distribution OER".
- Box 5.1: Post-harvest losses and reduction strategies for animal products in Nigeria Attribution: AI generated. Suggested OER search string: "post-harvest losses animal products Nigeria beef milk poultry eggs fish OER box".
- Figure 5.2: Domestic and export certification requirements flow diagram Attribution: AI generated. Suggested OER search string: "Nigerian animal products export certification requirements HACCP NAFDAC EU OER diagram".
- Box 5.2: Career pathways and professional bodies for animal products technology graduates Attribution: AI generated. Suggested OER search string: "career pathways animal products technology Nigeria NAFDAC NIAS HACCP auditor OER box".