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Description of cattle breeds in Nigeria and their potential in milk production

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Dedication

I would like to dedicate this work to my parents, Mallam Garba Idris and Hajiya Sadiya Mohammed, who have shaped my life in every way possible. Your love, guidance, and sacrifices have been the foundation of my journey.

To my father, thank you for instilling in me a strong work ethic, resilience, and a passion for knowledge. Your belief in my abilities has propelled my determination to pursue excellence. Your constant encouragement has given me the strength to overcome challenges and reach for my goals.

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With all my love and appreciation.

Abstract

This work explores the diverse characteristics of cattle breeds found in Nigeria and evaluates their potential for milk production. Nigeria boasts a rich diversity of cattle breeds, each with unique traits and adaptations to local environments.

These breeds include the White Fulani, Sokoto Gudali, Adamawa Gudali, among others. The study examines the physical attributes, milk yield, lactation period, and environmental adaptability of these breeds. Furthermore, it investigates the socio-economic significance of milk production from these breeds in Nigeria, considering factors such as cultural practices, market demand, and livelihood sustenance. The findings highlight the factor hindering milk production and the importance of understanding the distinct characteristics of each breed to optimize milk production and enhance the overall dairy industry in Nigeria.

Recommendations are provided for sustainable breeding practices, improved animal husbandry techniques, and policy interventions to harness the full potential of Nigeria's cattle breeds for milk production.

Keywords: cattle breed, milk, milk production, Nigeria.

Résumé

Ce travail explore les diverses caractéristiques des races bovines présentes au Nigeria et évalue leur potentiel de production laitière. Le Nigeria possède une grande diversité de races bovines, chacune ayant des caractéristiques uniques et s'adaptant à l'environnement local.

Ces races comprennent notamment la White Fulani, la Sokoto Gudali et l'Adamawa Gudali. L'étude met un évidence les attributs physiques, le rendement laitier, la période de lactation et l'adaptabilité environnementale de ces races. En outre, elle étudie l'importance socio-économique de la production laitière de ces races au Nigeria, en tenant compte des facteurs tels que les pratiques culturelles, la demande du marché et les moyens de subsistance. Les résultats mettent en évidence les facteurs qui entravent la production laitière et l'importance de comprendre les caractéristiques distinctes de chaque race pour optimiser la production laitière et améliorer l'ensemble de l'industrie laitière au Nigeria.

Des recommandations sont formulées pour des pratiques d'élevage durables, des techniques d'élevage améliorées et des interventions politiques afin d'exploiter tout le potentiel des races bovines du Nigeria pour la production laitière.

Mots-clés : race bovine, lait, production laitière, Nigeria.

الملخص

يتناول هذا العمل الخصائص المتنوعة لسلالات الماشية الموجودة في نيجيريا ويقيّم إمكاناتها لإنتاج الحليب .تتمتع نيجيريا بتنوع غني في سلالات الماشية، كل منها يتميز بسمات فريدة وتكيفات مع البيئات المحلية .تشمل هذه السلالات الفولاني الأبيض، غودالي سوكوتو، غودالي أداماوا، وغيرها .تدرس الدراسة الصفات الجسدية وإنتاجية الحليب وفترة الإرضاع وقدرة هذه السلالات على التكيف مع البيئة .علاوة على ذلك، تستكشف الدراسة الأهمية الاجتماعية والاقتصادية لإنتاج الحليب من هذه السلالات في نيجيريا، مع الأخذ في الاعتبار عوامل مثل الممارسات الثقافية، الطلب في السوق، ومعيشة الأفراد .تسلط النتائج الضوء على العوامل التي تعيق إنتاج الحليب وأهمية فهم الخصائص المميزة لكل سلالة لتحسين إنتاج الحليب وتعزيز صناعة الألبان بشكل عام في نيجيريا .تُقدم التوصيات لممارسات تربية مستدامة، وتحسين تقنيات تربية الحيوانات، وتدخلات السياسات لاستغلال الإمكانات الكاملة لسلالات الماشية في نيجيريا لإنتاج الحليب.

الكلمات المفتاحية :سلالة الماشية، الحليب، إنتاج الحليب، نيجيريا.

Table Of Content

List of tables
List of figures
List of abbreviations

List of tables

List of figures

List of abbreviations

FAO: Food and Agricultural Organization

FAOSTAT: Food and Agricultural Organization Statistics

FFA: Free Fatty Acid

FMAFS: Federal Ministry of Agriculture and Food Security

FMARD: Federal Ministry of Agriculture and Rural Development

NASS: National Agricultural Sampling Survey

NBS: National Bureau of Statistics

NNLRS: Nigerian National Livestock Research Survey

NPC: National Population Commission

UN: United Nations

UNFPA: United Nations Population Fund

WHO: World Health Organization

Introduction

Food self-sufficiency is one of the most important priorities for the functioning of modern economies.

Milk self-sufficiency is perceived as the ability of the entire country to cover domestic demand for milk, while taking into account the possibilities of foreign exchange of milk and milk products (1). However, this is not the case for many African countries including Nigeria. Despite the abundance of cows on the continent, it is startling that Africa presently falls short of producing enough milk to fulfil its own requirements, how can nations and communities talk of prosperity of future generation without guaranteeing regular access to milk for its children and citizens.

Milk plays a vital role in the daily lives of communities in various ways, both in its production and consumption. This holds true because milk is among the primary sources of animal protein crucial for human nutrition, and continues to be a crucial element in economic sustainability through job creation and income generation (2).

This study provides an in-depth analysis of the Nigerian dairy sector, focusing on the different cattle breeds, production systems, as well as the socio-economic and environmental factors influencing milk production. By examining the constraints and opportunities within the dairy industry, the research aims to identify strategic interventions that could enhance productivity and sustainability. The findings are crucial for policymakers, stakeholders, and researchers dedicated to improving food security and agricultural efficiency in Nigeria.

The first part is a bibliographic overview which is divided into three chapters:

- The first chapter elaborates on milk and milk production, as well as highlighting the components of milk.
- The second chapter focused on the analysis of the factors influencing milk production enumerating genetic, physiological, environmental, biological and management factors.
- The third one identifies the dairy cattle breeds that are world widely recognized for their high milk yield

The fourth chapter is organized as follows: the initial sections present an overview of Nigeria's geographical and climatic conditions and their impact on dairy farming. Subsequent sections detailed the demographics and distribution of the cattle population, highlighting the predominant breeds and their characteristics. The core of the study analyses the various dairy production systems, their efficiencies, and the challenges they face. The concluding sections propose actionable recommendations to address these challenges and improve milk production in Nigeria, thus contributing to the broader goals of agricultural development and economic growth.

CHAPTER 1: MILK AND MILK PRODUCTION

1.1 Milk

1.1.1 Definition

Milk is defined for commercial purposes as the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows, which contains not less than 8.25% of milk solids not fat and not less than 3.25% milk fat (3).

Milk is a white liquid produced by the mammary glands of mammals for feeding their young ones. It is secreted as a natural process in the mammary glands after parturition (4). According to the FAO/WHO Codex Alimentarius Commission, milk is a substrate whether processed, semi-processed or raw, that is intended for human consumption.

Although there are several milk products, the general term milk should only refer to cow's milk, produced by healthy animals and excluding the lactic secretion between 15 days before and 7 days after parturition, or until it is almost completely free from colostrum. This definition should exclude completely the so-called milk products of vegetable origin like "soy milk," "almond milk," etc. These should be called "beverages" according to their origin, such as "soy beverage," as previewed in the European Union legislation (5).

1.1.2 Composition of milk

Milk is a very complex fluid containing several hundred molecular species (several thousand if all triglycerides are counted individually). The principal constituents are water, lipids, carbohydrates (lactose) and proteins. In addition, there are numerous minor constituents, mostly at trace levels, e.g. minerals, vitamins, hormones, enzymes and miscellaneous compounds (6).

At macronutrient level, bovine milk is typically composed of water (85–87%), fats (3.8–5.5%), proteins (2.9–4.0%) and carbohydrates (5%).

At micronutrient level, bovine milk contains many bioactive compounds including vitamins, minerals, biogenic amines, organic acids, nucleotides, oligosaccharides, and immunoglobulins (7).

Table 1: Composition of bovine milk (8).

Milk composition	Average percentage %
Water	86.6
Total Solids	12.7
Fat	4.1
Proteins	3.7
Lactose	5.0
Ash (Minerals)	0.7

Milk occurs in solution, suspension or as an emulsion in water: fat and liposoluble vitamins as an emulsion; protein and mineral salts bound to casein micelles in suspension; and carbohydrates (lactose), minerals, non-protein nitrogen compounds and hydro soluble vitamins in solution (9).

1.1.1.1 Water

Milks of cows contain more water than any other constituent. Bovine milk is typically composed of water (85–87%) (7). The other constituents are dissolved, colloidally dispersed and emulsified in water. The dissolved solutes in bovine milk aggregate about 0.3 M and depress the freezing point by about 0.54°C. The activity of water (*aw*) in milk, which is the ratio of its vapor pressure to that of air saturated with water, is about 0.993. A small amount of the water of milk is "bound" so tightly by proteins and by the fat globule membrane that it does not function as a solvent for small molecules and ions (3).

1.1.1.2 Lipids

Lipids (commonly called fats, which are liquid or solid respectively at ambient temperature) are those constituents of tissues, biological fluids or foods that are soluble in an apolar a solvent, e.g diethyl ether, chloroform or carbon tetrachloride. Historically, the fat of milk was regarded as its most valuable constituent and, until recently, milk was valued largely or totally on its fat content (6).

In average, milk contains about 33 g of total lipid (fat)/L. Triacylglycerols, which account for about 95% of the lipid fraction. Each triacylglycerol molecule is built with a fatty acid combination giving the molecules liquid form at body temperature. Other milk lipids are diacylglycerol (about 2% of the lipid fraction), cholesterol (less than 0.5 %), phospholipids (about 1%), and free fatty acids (FFA) accounting to less than 0.5% of total milk lipids. Increased levels of FFA in milk might result in off-flavours in milk and

dairy products, and the free volatile short-chain fatty acids contribute to the characteristic flavour of ripened cheese (10).

Under normal conditions saturated fatty acids account for 70% of the total fatty acid content, monounsaturated fats account for 27% and dienes and trienes for only 3% (11).

1.1.1.3 Proteins

Milk contains 30–36 g/L of total protein and it rates very high in nutritive quality. Milk proteins are classified as either caseins or whey proteins. All the caseins exist with calcium phosphate in a unique, highly hydrated spherical complex known as the casein micelle. Such complexes vary in size from 30 to 300 nm in diameter, with a small percentage approaching 600 nm (8).

- **Caseins**

The caseins of milk may be subdivided into four main classes; $\boldsymbol{\alpha}$-Casiens ($\boldsymbol{\alpha}S_1$-casein and $\boldsymbol{\alpha}S_2$-casein), $\boldsymbol{\beta}$-casein, $\boldsymbol{\gamma}$-casein and $\boldsymbol{\kappa}$-casein. Of these all except $\boldsymbol{\gamma}$-casein are mammary gland gene products, $\boldsymbol{\gamma}$-casein results from post translational proteolyis of $\boldsymbol{\beta}$-casein (11).

- **Whey proteins**

Whey proteins contains α-Iactoglobulins and β-Iactalbumins, proteose-peptones (partly derived from hydrolysis of β-casein) and small quantities of the blood-derived proteins, serum-albumin and immunoglobulins (Damodaran et al., 2008).

Table 2: Concentrations of major proteins in milk (8).

Proteins	Concentration g/L	Approximate percentage of total proteins
Caseins	**24-28**	80
α-casein	15-19	42
β-casein	9-11	29
γ-casein	3-4	9
κ-casein	1-2	4
Whey proteins	**5-7**	**20**
α-lactoglobulin	1-1.5	4
β-lactoglobulin	2-4	9
Proteose-peptones	0.6-1.8	4
Blood proteins		
Serum albumin	0.1-0.2	1
Immunoglobulin	0.6-1.0	2

1.1.1.4 Carbohydrates

Lactose is the main carbohydrate present in milk. It is a disaccharide composed by glucose and galactose (5). Lactose is the major solid constituent of milk; its concentration varies with yield between 4.2 and 5.0%. The lactose content usually being lowest in late lactation and/or in milk from animals suffering from udder disease (11). Carbohydrates other than lactose in milk include monosaccharides (galactose), neutral and acid oligosaccharides, and glycosyl groups bound to proteins and lipids (3).

1.1.1.5 Minerals

Milk is a good source of calcium, magnesium, phosphorus, potassium, selenium, and zinc. Many minerals in milk are associated together in the form of salts, such as calcium phosphate. In milk approximately 67% of the calcium, 35% of the magnesium, and 44% of the phosphate are salts bound within the casein micelle and the remainder are soluble in the serum phase. The fact that calcium and phosphate are associated as salts bound with the protein does not affect the nutritional availability of either calcium or phosphate (5).

Table 3: Average milk mineral content (5).

Minerals	Concentration mg/100g
Calcium	119-124
Phosphorus	93-101
Magnesium	11-14
Potassium	151-166
Zinc	0.4-0.6

Milk contains small amounts of copper, iron, manganese, and sodium and is not considered a major source of these minerals.

1.1.1.6 Vitamins

The milk vitamin profile includes liposoluble (A, D, E) and hydro-soluble vitamins (B complex and vitamin C) (5).

- **Hydro-soluble vitamins**

Milk contains the water-soluble vitamins, vitamin B_1 (thiamine), Vitamin B_2 (riboflavin), Vitamin B_3 (niacin), Vitamin B_5 (pantothenic acid), vitamin B_6 (pyridoxine), vitamin B_{12}

(cobalamin), Vitamin C, and folate (Vitamin B_9). Milk is a good source of thiamine, riboflavin and Cobalamin. Milk contains small amounts of niacin, pantothenic acid, pyridoxine, vitamin C and folate (12).

- **Liposoluble vitamines**

Milk contains the fat-soluble vitamins A, D, E, and K. The content level of fat-soluble vitamins in dairy products depends on the fat content of the product. Reduced fat (2% fat), low-fat (1% fat), and skim milk must be fortified with vitamin A to be nutritionally equivalent to whole milk. Fortification of all milk with vitamin D is voluntary. Milk contains small amounts of vitamins E and K and is not considered a major source of these vitamins in the diet (13).

Table 4: Vitamin content in milk (5)

Vitamins	Concentration mg/100g
Hydro-soluble Vitamins	
Vitamin C	2.0
Vitamin B_1	0.04-0.05
Vitamin B_2	0.16-0.17
Vitamin B_3	0.08-0.09
Vitamin B_6	0.04
Vitamin B_{12}	0.35-0.50
Folate (vit B_9)	5-5.2
Liposoluble Vitamins	
Vitamin A	59
Vitamin D	0.05
Vitamin E	0.04
Vitamin K	0.005

1.1.1.7 Enzymes

Milk contains a large number of enzymes. Although present in small quantities, some are of considerable importance in determining the stability of milk during storage. Proteases and lipases can affect the flavour and protein stability of milk, while oxidoreductases also affect flavour, especially in the lipid fraction. Plasmin is the major proteinase in milk and lipoprotein lipase is the principal lipolytic enzyme in milk (14).

Although alkaline phosphatase is of no importance with respect to milk stability, it is one of the most widely known enzymes in milk, this is due to its almost complete inactivation by pasteurization (11).

1.1.1.8 Hormones

Milk hormones come from blood that circulates the mammary gland, although they are found in minute quantities. Among the hormones found in milk, prolactin has been the most extensively studied. It provokes and sustains milk secretion by acting directly on the mammary gland (15).

1.2 Milk production

In nature, milk has the irreplaceable function of being the only nourishment source for the new-born until the digestive tract is able to digest solid food (9). The selection process carried out on dairy cows by humans over thousands of years has resulted in a milk yield remarkably higher than that required to feed the new-born calves and, above all, an increase in lactation period. Cow's milk represents about 90.8% of the world milk production (16).

1.2.1 The anatomical basis of milk production

Lactation is a physiological process characterized by the synthesis, secretion, ejection and removal of milk. This physiological function is made possible by captivation, or passive and active filtration, of organic and inorganic compounds and water from the blood fluid by the secretory epithelium of the mammary gland. The secretory cells, which are roughly cuboid in shape and markedly polarized in structure, are arranged to form spherical structures (alveoli), with a hollow lumen into which milk is secreted (9).

1.2.2 Synthesis of milk

Milk components are principally synthesized by the secretory cells of the mammary gland from precursors absorbed from blood. These precursors are derived directly or indirectly from nutrients in the diet. The mammary epithelium also acts as a selective barrier, permitting the transfer of selected substances from the blood to the alveolar lumina without changes in their chemical composition (9).

However, milk synthesis depends not only on the supply of nutrients to the mammary gland but also on the regulation of their use through physiological and endocrine controls.

1.2.3 Milk secretion

Milk secretion is the transport mechanism of neosynthesized compounds and substances extracted from the blood or interstitial fluid into the alveolar lumen of the mammary gland.

Most of the components of the aqueous phase of milk are secreted by exocytosis.

Proteins and lactose are packaged into secretory vesicles that move to the plasma membrane of the alveolar cells, where they fuse and release their contents into the alveolar lumen by exocytosis.

The mechanism for fat secretion is unique to the mammary gland, because lipid droplets become enveloped in the apical membrane and are secreted into the alveolar lumen surrounded by a layer of plasma membrane composed of phospholipids (9).

1.2.4 Ejection of milk

Milk ejection is the removal of milk from the alveoli through the contraction of the myoepithelial cells surrounding the alveoli and the small ducts when a neuroendocrine milk ejection reflex occurs. The neuroendocrine mechanism is activated by sensory receptors in the teat at suckling or milking, and by conditioned stimuli of events preceding the suckling or milking. The nerve signals reach the posterior lobe of the pituitary gland (neurohypophysis) via the spinal cord and oxytocin is released into the blood from this gland (17).

On reaching the mammary gland, oxytocin causes the myoepithelial cells surrounding the alveoli to contract, and the stored milk is forced down the galactophore and gradually reaches the cistern. In this way, the secreted milk, in the interval between suckling or milking, is distributed in different proportions between the alveoli and the small diameter ducts (alveolar milk), and the large-diameter ducts and cistern (cisternal milk) (18).

The ejection reflex can be induced by conditioned stimuli such as the sight and noise of the milking parlour or the presence of the milkers. Stress, pain or fear can inhibit the milk ejection reflex. In these situations, adrenalin, which is a potent vasoconstrictor of mammary vessels, may be released from the adrenal medulla. The reduction of mammary blood flow prevents oxytocin from reaching the mammary gland via the blood, with a consequent lack of ejection (9).

1.2.5 Removal of milk

Milk stored in the mammary gland can be removed by suckling or milking. Just prior to suckling or milking, the secreted milk is distributed in the mammary gland in two parts: 'alveolar milk' stored in the lumina of the alveoli, smaller ducts and ductules, and 'cistern milk' stored in the large ducts and in the cistern. The ratio of alveolar to cistern milk varies depending on the cistern volume, the breed and also the physiological state of the animal.

Milk removal is essential for the maintenance of lactation. Accumulation of milk in the cistern and duct system, for extended milking intervals, can reduce the rate of milk secretion (9).

1.2.6 Lactation curve

A lactation curve represents the evolution over time of cows' milk production during a specific lactation cycle. This cycle is the period from lactation onset after calving until the cow's milk dries up. Lactation curves generally reach their peak yield after calving and then decrease steadily from then until drying up.

Lactation curves allow the evaluation of important milk production characteristics such as maximum production and times to maximum production or persistency (19).

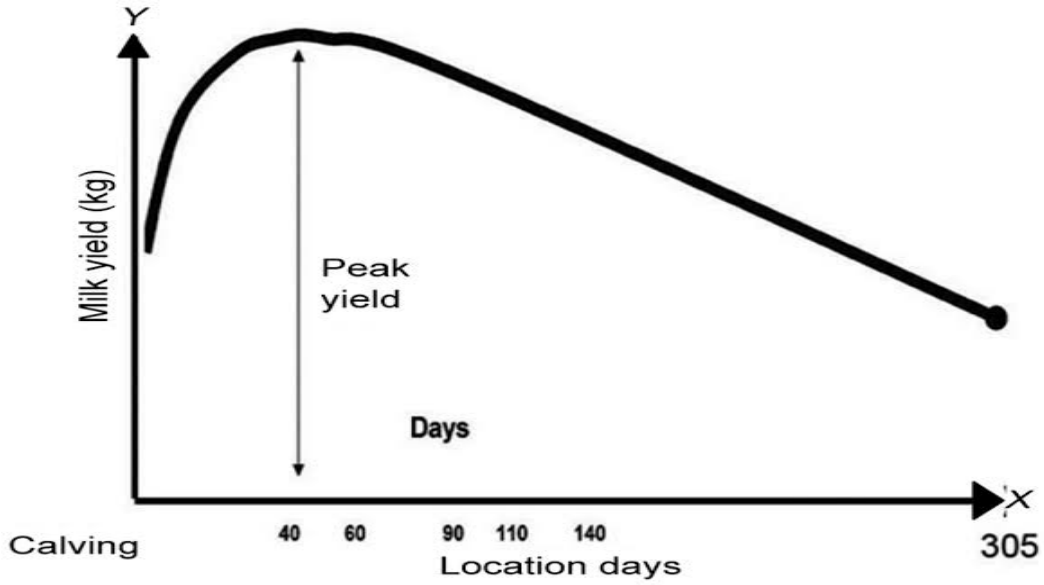

Figure 1: Standard shape of the lactation curve for dairy cattle. The plot shows the milk production as function of the days after the parturition (19).

CHAPTER 2: FACTORS INFLUENCING MILK PRODUCTION

2.1 Introduction

Milk production in cattle from dairy farms is influenced by a series of factors, such as factors that influence individual production and factors that influence total, delivered milk production. Since the cow milk production of each dairy cow varies, the factors that influence it can be grouped into those with direct and those with indirect influence (20). Under normal situations, milk production increases during the first six weeks of lactation and then gradually decreases. The actual amount of milk produced during the lactation period is affected by several factors including:

2.2 Genetic factors

2.2.1 Breed

This is a key genetic factor that determines the milk production potential of dairy cows. Each breed has a different genetic potential. There are breeds specializing in milk production, mixed production and meat production. Breeds that are specialized for milk production produces large amounts of milk such as the Frisian, Holstein etc. However, the shape of the lactation curve remains the same. The effect of breed influences production parameters linked to production potential (21).

2.2.2 Individual

Within each breed, there are exceptional individuals that can produce several times more milk than the average for that breed. However, even within the same breed and under identical conditions, dairy cows may vary in their milk yield. These differences are attributed to genetic variations among breeds and populations (21).

2.3 Physiological factors

2.3.1 Age at first calving

Total milk production increases with the age of the cow, which is related to the general weight of the cow and the growth rate of the mammary gland. Age at first calving is a very important parameter, it is essentially related to breeding and feeding conditions.

Thus, the increase in milk production is linear between 24 and 31 months of age, heifers that calve at an age of around 24-31 months yield more milk at first lactation and their production is higher (22).

2.3.2 Lactation number

Milk production increases from the 1st to the 3rd lactation, it becomes maximum at the 3rd or 4th lactation and it begins to decrease during the fifth lactation. This is related to the fact that udder development in the heifer continues during its first lactations. This development is maximum towards the 3rd lactation. Milk production begins to decrease from the 5th lactation as a result of aging of the mammary tissue (23).

2.3.3 Gestation

Gestation has an inhibitory effect on milk production. Most of the reduction in milk yield occurs after the 5th month of gestation. By the 8th month of gestation, milk yield may be 20% less for that month compared with non-pregnant cow. Milk production decreases physiologically, gestation is a factor which depresses lactation. Depressive effect linked to progesterone which has a negative effect on the secretion of prolactin (PRL) (24).

2.4 Environmental factors

2.4.1 Season of calving

The effect of season of calving on milk yield is confounded by breed, the stage of lactation, and climatic condition. Cows calving in late fall to spring produce more milk (up to 8% more) than cows calving in the summer. This is likely due to an interaction between day light and ambient temperature. Seasonal differences have become less significant because of better feeding and management of the dairy cow (23).

Season of calving influences cow milk production particularly on dairy farms where feeding is not even during the year. Dairy cows that farrow in spring and summer produce larger amounts of cow milk in the first lactation months, which coincides with feeding based on green fodder that stimulated cow milk secretion (23).

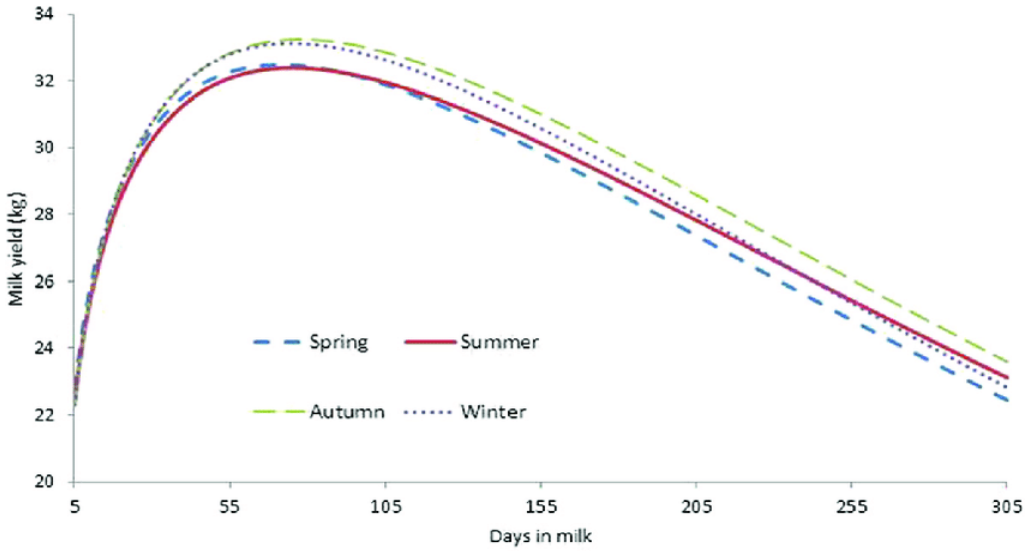

Figure 2: The shape of the lactation curve for milk yield according to season of calving (25)

The minimum milk production is observed in winter corresponds to a period of the year that is characterized by short days, the cows are kept inside the barn and receiving a feed consisting mainly of dry fodder or silage.

The peak in milk production is observed in the spring (spring peak), which corresponds to the favourable period of production. Cows receive good feeding (green fodder and grazing) in long days.

2.4.2 Ambient temperature and humidity

At high temperatures and humid climates, animals encounter challenges to balance the metabolic heat production and dissipate enough heat to their surroundings The effect of ambient temperature on milk yield is dependent upon the breed. Holsteins and the other larger breeds are more tolerant to lower temperatures, whereas the smaller breeds particularly the Jersey, are much more tolerant to high temperatures (26).

The comfortable environmental temperature for the dairy cows (Holsteins) is between 5°C (lower critical temperature) and 25°C (upper critical temperature). Milk production declines when environmental temperature exceeds 27°C. Dairy cows use behavioural and physiological strategies to cope with heat stress, including reduced feed intake and taking more water to decrease metabolic heat production, and ultimately milk yield is reduced (27).

The reduction in milk yield is largely due to drop in feed intake. High temperature affect high producing cows more than low producers and its effect is substantially greater during the peak of lactation.

2.4.3 Photoperiod

The control of mammary growth is a complex process involving many hormones, as well as external influences such as photoperiod. Photoperiod is the relative duration of light and dark exposure within a day. It is an important environmental cue used by animals to predict and prepare for the change of seasons. During the first allometric phase, exposure of dairy heifers to a long-day photoperiod of 16 h of light and 8 h of dark is associated with an increase in prolactin (PRL) concentration, mammary development, and milk yield (28).

2.5 Biological factors

2.5.1 Diseases

Milk production declines in case of diseases like dystocia, retained placenta, metritis, cystic ovaries, milk fever, displaced abomasum, mastitis and ketosis and many others.

The main disease that affects milk yield of dairy cows is mastitis. It impairs the ability of secretory tissue to synthesize milk components and destroys the secretory tissues and consequently lowering milk yield. A decrease in production persists after the disappearance of the clinical signs of mastitis due to destruction in the secretory tissues (29).

2.6 Management factors

2.6.1 Length of dry period

A dry period (DP) of 42 to 60 days is common practice in dairy cow management. The conventional DP facilitates the replacement of senescent mammary epithelial cells and maximizes milk yield in the next lactation (30).

The length of the dry period has an influence on subsequent lactation. The recommended DP is between 40 and 60 days (6 to 8 weeks), as the mammary gland needs a dry period for complete regeneration of the mammary tissue and maximize production during the following lactation (resting period of the mammary tissue). This period enables maximum milk production to be achieved in the subsequent lactation.

Generally speaking, total elimination of the dry period will cause a milk production loss of over 15% in the following lactation. Also, extending the duration of the dry period (longer than 70 days) will result in a small increase in milk production, and is economically unjustified (31).

2.6.2 Milking

1.1.1.9 Milking condition

1.1.1.10 Any stress produced during milking will have a negative impact on the ejection of milk (milk retention by the cow) and therefore there will be a decrease in the amount of milk obtained compared to the amount obtained under non-stressful milking conditions (18).

1.1.1.11 Milking frequency

Cows are usually milked twice daily. Milking twice a day yields at least 40% more milk than once a day. Increasing milking frequency to 3 times a day increases milk yield by up to 20% (range 5-20%). The increase is usually highest for first lactation cow and declines as the cow gets older. The most likely reasons for increased milk production as frequency of milking increases are: i) less intramammary pressure generated with frequent milking, ii) increased stimulation of hormone activity favourable of milk production and iii) less negative feedback on the secretory cells due to the accumulation of milk components. The practice has been implemented to increase milk yield (32).

1.1.1.12 Milking interval

Cows are usually milked at equal intervals (12 hours interval for 2 times milking). Cows milked at unequal intervals produce less milk than those milked at equal intervals. The reduction in milk yield is more in high producing cows than in low producing ones. Incomplete milking for several consecutive days can permanently reduce milk yield for the entire lactation. Milking time for most cows is 5-6 minutes per cow (32).

1.1.1.13 Residual milk and available milk

Residual milk can be defined as the amount of milk left in the udder after milking is completed. About 10-20% of total milk is left in the udder as residual milk. Residual milk can be measured by giving the cow oxytocin and one minute later, milking the cow again. Part of the residual could never be recovered by conventional milking procedures

while another fraction can be collected if the amount of residual milk is large due to poor milking procedure. This proportion of milk is referred to as available milk. Available milk reflects how well the cow was stimulated for milking. If the cow is not well trained for milking, the amount of available milk uncollected will be great. Large amount of residual milk reduces daily milk production, reduces lactation production and the cow will have fewer days in milk (33).

CHAPTER 3: DAIRY CATTLE BREEDS

3.1 Introduction

Dairy cattle form a unique niche among animals used for human purposes. They have been selected out among cattle to perform one very specific purpose, the production of milk. While many dairy cattle also have value as beef or draught animals, there are no other types of livestock that have been selected as systematically, and for as many years, as dairy cattle have been selected to produce milk (34). In many parts of the world, cattle are raised for dual (meat and milk) or even triple (meat, milk and draught) purposes. Breeds of cattle frequently show the effects of such multiple objectives. The dairy cattle breeds are those which have been specifically improved, for milk production.

3.2 Domestication of cattle

Cattle have been domesticated for several thousand years. Stone Age hunters left us with pictures on cave walls of the aurochs (*Bos primigenius*) which are the progenitors of the cattle of today. There is evidence of domestication of cattle as long as 8000 years ago in central and western Asia (35).

Cattle of the world fall into two classifications. All cattle are members of the genus *Bos*. Most cattle can be assigned either to species *taurus* or *indicus*. *Bos indicus* cattle typically have a pronounced hump on their shoulders while *Bos taurus* cattle are hump less. The hump is probably for energy storage and it also serves to increase surface area which is an aid in heat dissipation (34).

3.3 The concept of breed

Since domestication of cattle began, humans have attempted, through various means, to identify superior animals and retain them. The widely varying geographical areas in which cattle existed and the multiplicity of uses meant that cattle would develop in many diverse ways. It was inevitable that cattle would begin to fall into groupings which we have come to refer to as ‘breeds’(36). The term ‘breed’ is a difficult one to define precisely because it means different things to different people.

According to (37), a breed is a specific group of domestic animals having homogeneous appearance, homogeneous behaviour, and/or other characteristics that distinguish it from other organisms of the same species.

3.4 Dairy cattle breeds

Some of the major dairy breeds in world are (In alphabetical order rather in order of importance): Ayrshire, Brown Swiss, Guernsey, Holstein, Jersey, and Normande. All of these breeds are of the *Bos taurus* type. Each has been subjected to intense selection for increased milk production over the past several decades (34).

3.4.1 Ayrshire

1.1.1.14 Origin

The Ayrshire breed originated from the county of Ayr in Scotland, prior to 1800Bc. The county is divided into the three districts of Cunningham, in the more northern part, Kyle, which lies in the centre, and Carrick, which forms the southern part of the county. During its development, it was referred to firstly as the Dunlop, then the Cunningham, and finally, the Ayrshire (38).

1.1.1.15 Description

- **Appearance**: Ayrshires are red and white and purebred Ayrshires only produce red and white offspring (34). Actually, the red colour is a reddish-brown mahogany that varies in shade from very light to very dark.
- **Weight:** Ayrshire cattle are moderate in size with an average weight of 550–700 kg.
- **Characteristics:** prominent strongly attached and balanced udders, strong loins, long stooping from hip to pin bones, good spring of ribs and deep body capacity.

Figure 3: The Ayrshire cow (39)

1.1.1.16 Milk production potential

Ayrshire cows have high milk production potential 19-27 litres/day. The average milk yield is roughly 7000L/lactation with butter fat of 4.7%. Heifers generally come into milk at about two years of age (34).

3.4.2 Brown Swiss

1.1.1.17 Origin

Brown Swiss breed was originated in 2000 years B.C. where is now Switzerland, in its central region. It is considered the oldest dairy breed in the world. Besides, it is the second-largest lactation producing breed behind the Holstein breed. The breed was improved at the beginning of the 20th century in the United States towards the highest milk production (38).

1.1.1.18 Description

- **Appearance:** Brown Swiss cows are characterized, as their name suggests, by having a dark brown colour fur. Its hair is short and thin. It has excellent leg conformation thanks to its adaptability to the Swiss Alps, making it rustic on steep terrain.
- **Weight:** Brown Swiss cows weigh between 600-700Kg, being considered medium. Males can weigh between 900 and 1000kg.
- **Characteristics:** It has an excellent adaptability to the environment, standing between 0 and 3600 meters above sea level. Its physical conformation gives it a good strength and support according to its high production.

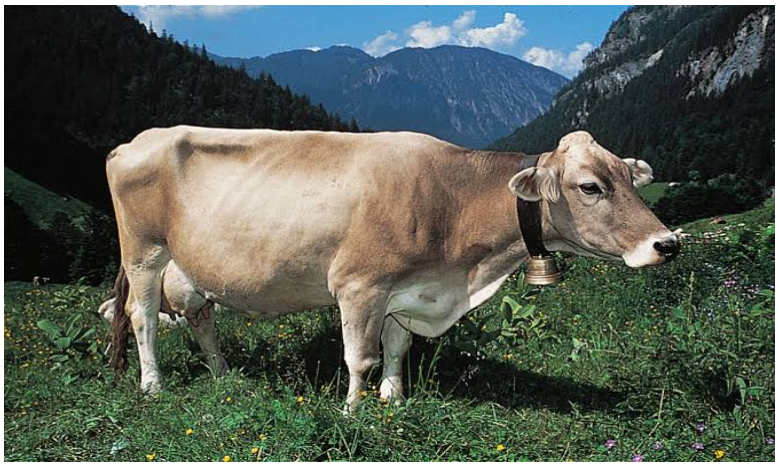

Figure 4: The Brown Swiss cow (40)

1.1.1.19 Milk production potential

Brown Swiss cows are close to the milk production of the Holstein breed, they are the second largest milk producing breed in the world. Brown Swiss cows can produce between 21-29 L/day. Also, they are the cattle breed that produces milk with the highest number of proteins and total solids (34). It has an excellent food conversion even when their diet is based on fodder (41).

3.4.3 Guernsey

1.1.1.20 Origin

Guernsey cattle developed on the island of Guernsey, which is one of the Channel Islands lying between England and France (38).

1.1.1.21 Description

- **Appearance:** Guernsey varies from yellow to reddish-brown with white patches.
- **Weight:** The Guernsey is of medium size intermediate to Holsteins and Jerseys in size 400–650kg.
- **Characteristics:** They have a finely tuned temperament, not nervous or irritable; physically the breed has good dairy conformation and presents the visual impression of a plain animal bred for utility rather than good looks (42).

Figure 5: The Guernsey cow (43)

1.1.1.22 Milk production potential

It shows a high milk production potential 18-26 L/day with moderate butter fat content 4.3%. Guernsey are efficient converters of feed to product, being of intermediate size, Guernsey produces their high-quality milk while consuming 20 to 30 percent less feed per 0.45kg of milk produced than larger dairy breeds. Guernsey reach reproductive maturity at an early age and can calve at 22 months of age (34).

3.4.4 Holstein

1.1.1.23 Origin

The Holstein breed also known as Holstein Friesians originated from Netherlands. It comes from the provinces of North Holland and Friesland. These two Dutch regions are characterized by humid and abundant vegetation. In European countries, there is a lineage called Frisian and in America the Holstein Friesian.

Holsteins were selectively bred and culled for many years to ensure a stock that would make the best use of the area's abundant grass resources. This practice resulted in a hearty efficient breed that is now used for dairy in more than 150 (34).

1.1.1.24 Description

- **Appearance:** Holstein cows have a recognizable pattern of black and white (or sometimes red and white) markings across their hides, with distinct pattern borders throughout.

- **Weight:** For Holstein Friesian, adult bulls have an average weight of 1050 kg, and adult cows weigh is 680 kg. Healthy calves can weigh over 40 kg at birth.
- **Height:** Averagely, the adult bulls have an elevation of 1.52m and the females of 1.45m.
- **Characteristics:** Holstein cows are characterized by being the heaviest breed of dairy cows. They have a large udder according to their large production. Holstein's body is wide at the back, angled, and low musculature, due to their dairy approach.

Figure 6: Holstein cow (44)

1.1.1.25 Milk production potential

The Holstein breed is the best in the world in milk production. For decades a high-quality genetic selection has been made to obtain specimens with high milk yields. It is best adapted to cold or temperate climates, while in warm regions it is significantly affected.

The average Holstein milk production varies from 22.3 kg/day for first lactating cows to 24.1 kg/day for second lactating cows (45).

The amount of milk produced depends on multiple factors such as the environment and nutrition. Therefore, in systems with concentrated diets, an average of 10,000-12,000 litres of milk per lactation (305 days) has been reported. On the other hand, in forage-based diets, the production could be between 4000-5000 L of milk per lactation. For tropical countries as well as in Latin America, this may also vary. However, it is the preferred breed of dairy-producing cattle due to high production (34).

3.4.5 Jersey

1.1.1.26 Origin

The Jersey cows originated in an island with the same name, located in the English Channel between England and France. Their large productive capacity allowed them to adapt well in the most productive countries such as the US, Canada, or New Zealand (38).

1.1.1.27 Description

- **Appearance:** Jersey cows are small compared to other dairy cow breeds, with a predominantly light brown coloured hides, Jersey has a small head with large eyes, a front slit, and a dark snout. Regarding its conformation, it has refined angles and that give it excellent proportions.
- **Weight:** Jersey cows weigh on average 300-400kg in their adulthood; bulls weigh between 400-500kg.
- **Height:** The height of the withers of Jersey is 1.25 meters.
- **Characteristics:** Like the Holstein, the Jersey breeds have a good conformation to support the udders. Its limbs are thin according to its lightweight. It has short hair. Jersey is quite docile to handling and adapts well to areas inclined thanks to its long legs and lightweight.

Figure 7: The Jersey cow (46)

1.1.1.28 Milk production potential

Jersey cow is known for producing milk with high fat, protein, and total solids. These benefits translate into better quality milk and a better selling price. These productive advantages are better valued because of their excellent conversion with a diet based on fodder or pasture. Besides, the Jersey cow adapts very well to various types of soil or climate, being very resistant to moderate heat.

Jersey cows can reach a production of up to 10.000 litres per lactation. In tropical and extensive system conditions, it ranges from 20-22 L/day which amounts to 5000-6000 L/lactation (34).

Jersey's milk is rich in fat, especially in fatty blood cells which makes it an excellent source for dairy products such as cheeses. This advantage in some countries is translated a higher selling price.

3.4.6 Normande

1.1.1.29 Origin

The Normande breed takes its name from the region called Normandy, in France. The breed was obtained in the 19th century after the crossing of several breeds already disappeared. It has adapted well to the tropical countries of America. Normande is a dual-purpose breed with a focus on milk production (45).

1.1.1.30 Description

- **Appearance:** Its fur is white with coloured dots ranging from dark brown, to reddish or yellowish. It has spots around the eyes that give it the appearance of glasses and a dark snout. Its head is large.
- **Weight:** Females are large, can weigh between 700-800Kg. Males can weigh between 900 and 1100Kg. The weight is because of their dual-purpose status.
- **Height:** Normande cows can measure up to 140cm. Bulls can have a height up to 155cm.
- **Characteristics:** the Normande breed is characterized by its wide chest and abdomen, giving it a rectangular and solid appearance. It has proper leg conformation and an important musculature, ideal for meat production. Its back is wide and solid, providing good adaptation to the production of milk in large quantities. It has an admirable rusticity and docile behaviour (42).

Figure 8: A herd of Normande cattle (47).

1.1.1.31 Milk production potential

The average milk production of Normande varies from 14.3 kg/day for cows in the first to 21.2 kg/day for cows in the second lactation. In addition, Normande cows can produce between 6000-7000 litres of milk per lactation. The milk protein content is higher in Normande cows than in Holstein cows, their milk is also rich in fats (45).

Table 5: Breeds of *Bos taurus* used primarily for milk production (34)

Breed	Origin	Weight/Kg	Colour	Milk production		
				Milk Yield Kg/day	Protein %	Fat %
Ayrshire	Ayr, Scotland	550-700	Red and White	19-27	2.9-3.3	3.5-4.1
Brown Swiss	Switzerland	600-800	Light Brown	21-29	3.1-3.5	3.6-4.4
Guernsey	Guernsey, Channel Island	400-650	Fawn and white	18-26	3.1-3.5	4.2-4.8
Holstein	Netherlands'	600-800	Black and white	25-35	2.8-3.2	3.3-4.1
Jersey	Jersey,Channel Island	350-550	Fawn	19-25	3.1-3.9	4.1-4.9
Normande	Normandy, France	700-800	Reddish brown	21.2		

CHAPTER 4: ANALYSIS AND DATA REVIEW OF NIGERIA

4.1 Objective

The objective of this research is to comprehensively assess and characterize the current state of dairy production systems in Nigeria, with a focus on the pastoral, agro-pastoral, and commercial farming systems. This study aims to describe the productivity levels, management practices, and socio-economic impacts associated with each system. A significant aspect of this research involves analysing the milk production potential of various indigenous cattle breeds, including White Fulani, Sokoto Gudali, and Adamawa Gudali. By identifying the challenges and opportunities within these systems and understanding the milk yield capacities of different breeds, the research seeks to provide detailed insights and recommendations. These findings will inform policies and strategies to enhance the efficiency, sustainability, and overall contribution of dairy farming to Nigeria's agricultural sector and economy. Additionally, this research will explore the potential for improving local milk production to meet the growing demand, thereby reducing dependence on imports and ensuring food security.

4.2 Presentation of Nigeria

4.2.1 Location and topography

The Federal Republic of Nigeria is located along the western African coast. It is bordered by Niger to the north, Chad and Cameroon to the east and Benin to the west. The capital city of Nigeria is Abuja, which is located in the central part of the country. Lagos, the country's economic hub, is located along the south-western coast, close to the Benin border.

Nigeria lies between 4-14^{o} N latitude and 3-14^{o} E longitude, making it north of the equator and east of the Greenwich Meridian. Nigeria is 356,669 sq miles/ 923,768 sq km, almost four times the size of the United Kingdom! At its widest points, Nigeria measures 696 miles/ 1,120 km from north to south and 795 miles/ 1,280 km from east to west. Nigeria has 530 miles/ 853 km of coastline and comprises the Abuja Federal Capital Territory and 36 states.

The topography of Nigeria varies throughout the country. Generally, there are hills and plateaux towards the country's centre, surrounded by plains in the north and the south. The wide valleys of the Niger and Benue rivers are also flat.

Figure 9: Map of Nigeria (48)

4.2.2 Climate of Nigeria

Nigeria has a hot, tropical climate with some variations. There are 3 broad climatic zones. Generally, precipitation and humidity decline as you go from south to north. The three climatic zones are as follows:

- **Tropical monsoon climate in the south:** The rainy season extends from March to October in this zone. There are heavy rains, and the average annual rainfall is usually above 2,000 mm. It even gets up to 4,000 mm in the delta of the river Niger.
- **Tropical savanna climate in the central regions:** In this zone, the rainy season extends from April to September and the dry season from December to March. The average annual rainfall is about 1,200 mm.
- **Sahelian hot and semi-arid climate in the north:** Nigeria's driest zone. Here, the rainy season is the shortest, extending from June to September. The rest of the year is very hot and dry, as this portion of the country is closest to the Sahara Desert. The average annual rainfall in this zone is 500 mm-750 mm. Rainfall in this part of Nigeria is variable. Therefore, this zone is prone to both flooding and droughts.

The most significant temperature difference in Nigeria is between the coastal areas and its interior as well as between the plateau and the lowlands. On the plateau, the mean annual temperature varies between 21°C and 27°C whereas in the interior lowlands, temperatures are generally over 27°C. The coastal fringes have lower means than the

interior lowlands. Seasonal mean temperatures are consistently over 20°C throughout the country and diurnal variations are more pronounced than seasonal ones. Highest temperatures occur during the dry season, and vary little from the coast to inland areas. Similar to rainfall, the relative humidity in Nigeria decreases from the south to the north, with an annual mean of 88% (49).

4.2.3 Population of Nigeria

The projected population figure for Nigeria in 2022 was 216,783,381 comprising of 108,350,410 males and 108,432,971 females (50), making it the most populous country in Africa. It also has the 6th largest population in the world. The majority (54%) of the country's population falls within the 15-64 age cohort, while only 3% of the population is 65 years and older. Nigeria's population growth rate is 2.5%. Nigeria's population expanded quite rapidly over the past 30 years. It grew from 95 million in 1990 to 216.7 million in 2022, with projections suggesting it could exceed 400 million by 2050 (51).

4.3 Milk situation and production in Nigeria

4.3.1 Milk demand in Nigeria

Nigeria’s per capita consumption of milk was eight litres (8L) in 2023, below the global average of 44 litres, according to the Food and Agriculture Organization (FAO) thus leaving a deficit of 36 litres per capita. 89% of the milk consumed in Nigeria is Cow milk with goat and ewe milk estimated to be 8% and 2% respectively.

In urban areas, milk is consumed in a variety of forms, including fresh milk, powdered milk, evaporated milk, and as ingredients in processed dairy products like yogurt and cheese. In contrast, rural areas typically follow more traditional practices. Fresh milk is often obtained directly from local cattle and is either consumed fresh, fermented into yogurt, or used to make traditional cheese (52).

The Nigeria Agricultural Promotion Policy estimated that the milk demand in the country is over 2 million metric tonnes (MMT) per year (53). The figure below shows the annual milk demand in Nigeria from the year 2013-2021.

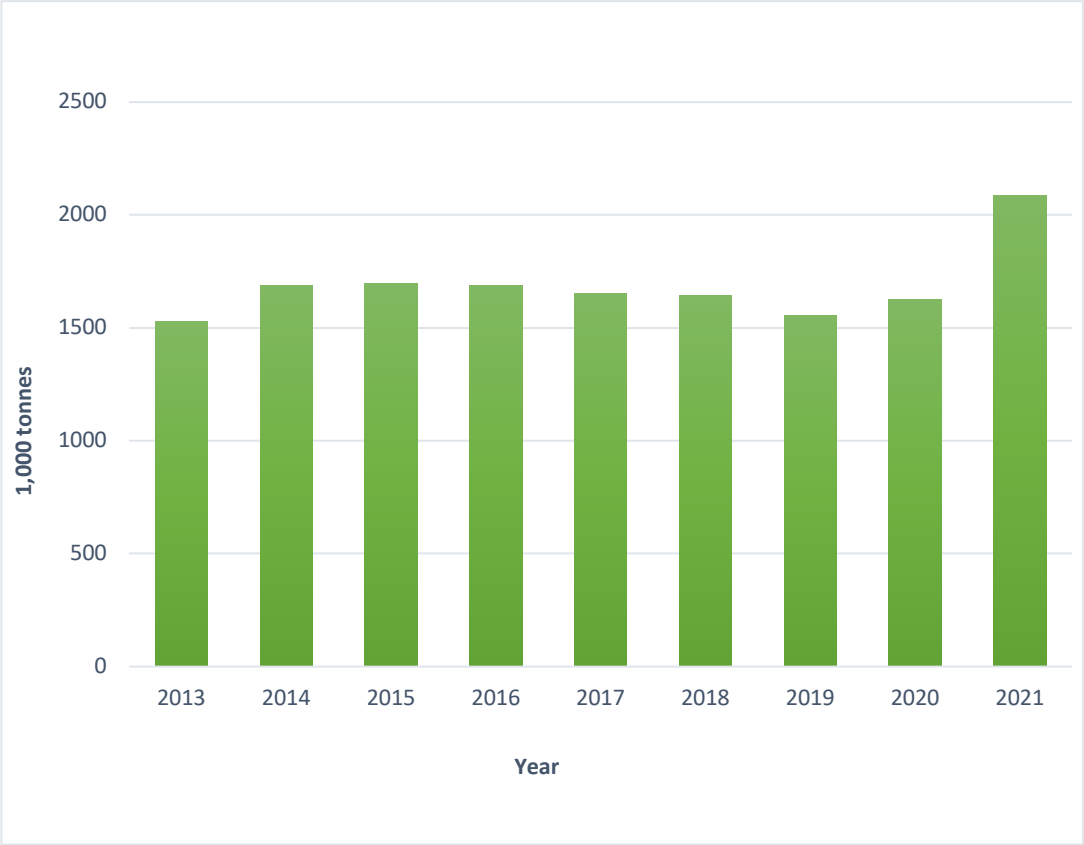

Figure 10: Annual milk demand in Nigeria (2013-2021) in metric tonnes (54)

4.3.2 Source of the milk consumed in Nigeria

Milk in the Nigerian market are sourced locally and internationally; the local milk production was reported to be around 0.6 million tone in the Nigerian agricultural promotion policy (53). In addition, milk production is lower than its demand, which is a clear indication of the need for improved efficiency to boost production, especially when considering the expected growth in the demand for milk (55).

Nigeria imports at least 60 per cent of the milk consumed in the country (56), with the remaining 40% produced locally. The graph below shows the amount of milk produced locally and the amount imported from 2013-2021.

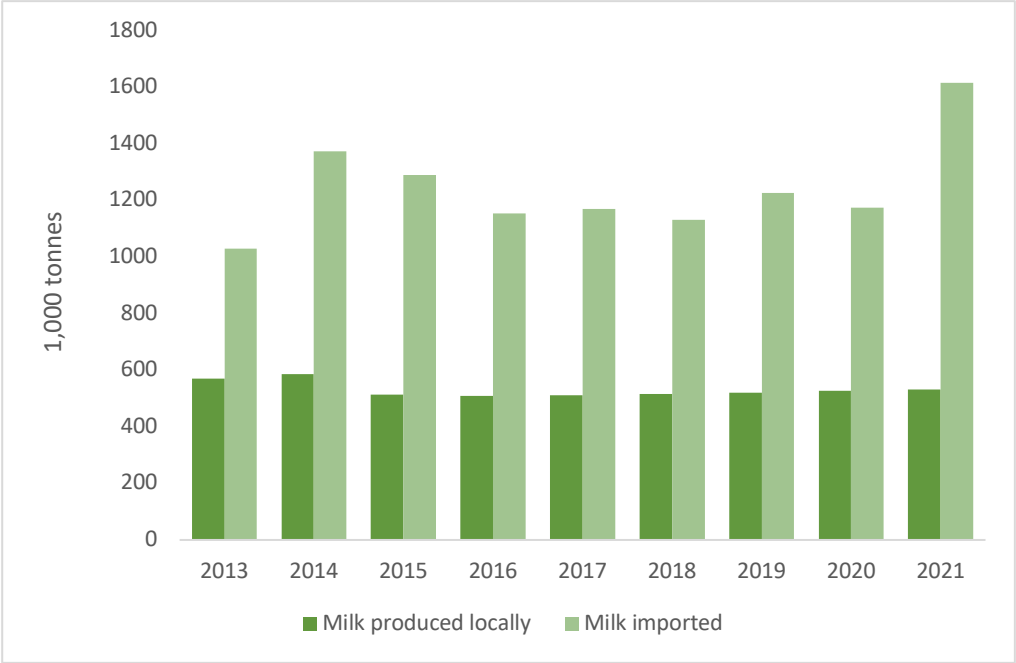

Figure 11: Milk produced locally and milk imported in Nigeria (2013-2021) in metric tonnes (54)

4.4 Nigeria cattle population

Nigeria has the fifth largest cattle population in Africa following Ethiopia, Sudan, Chad, and Tanzania, with an estimated 20.9 million cattle, which include 2.35 million dairy cows, (where 99% of these cattle are indigenous breeds) accounting for over 90% of the total annual milk produced in the country (57).

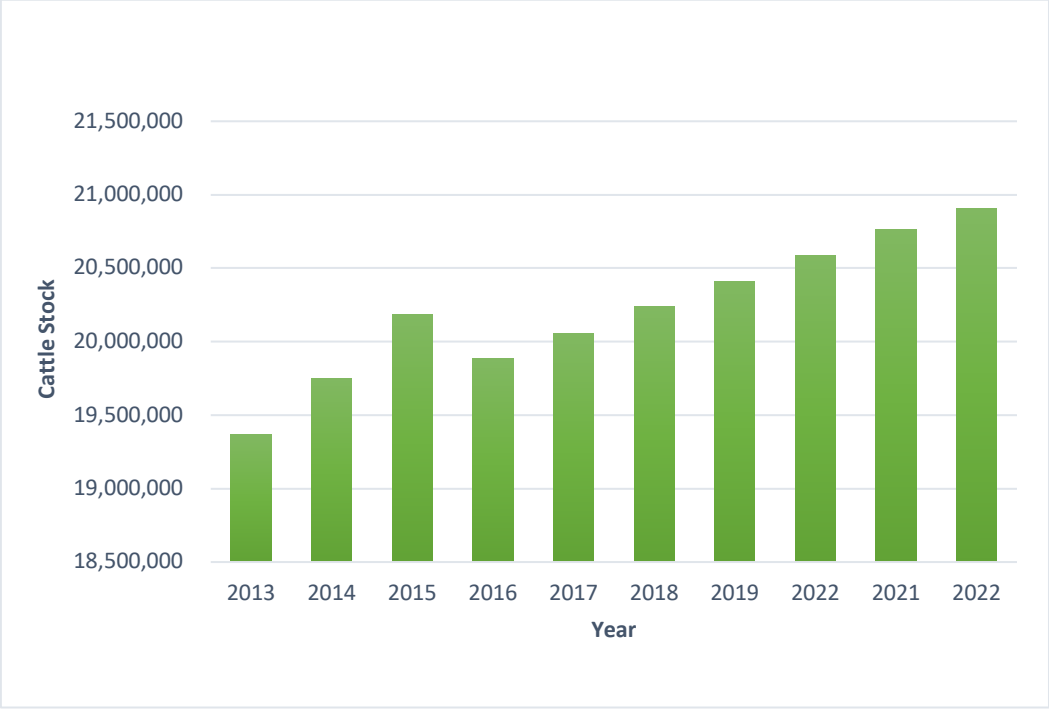

Figure 12: Cattle population in Nigeria (2013-2022) (54).

The cattle population is concentrated in the northern part of Nigeria, 99% of cattle are indigenous breeds. The remaining 1% consists of exotic and improved dairy cattle, which are found primarily in the central region.

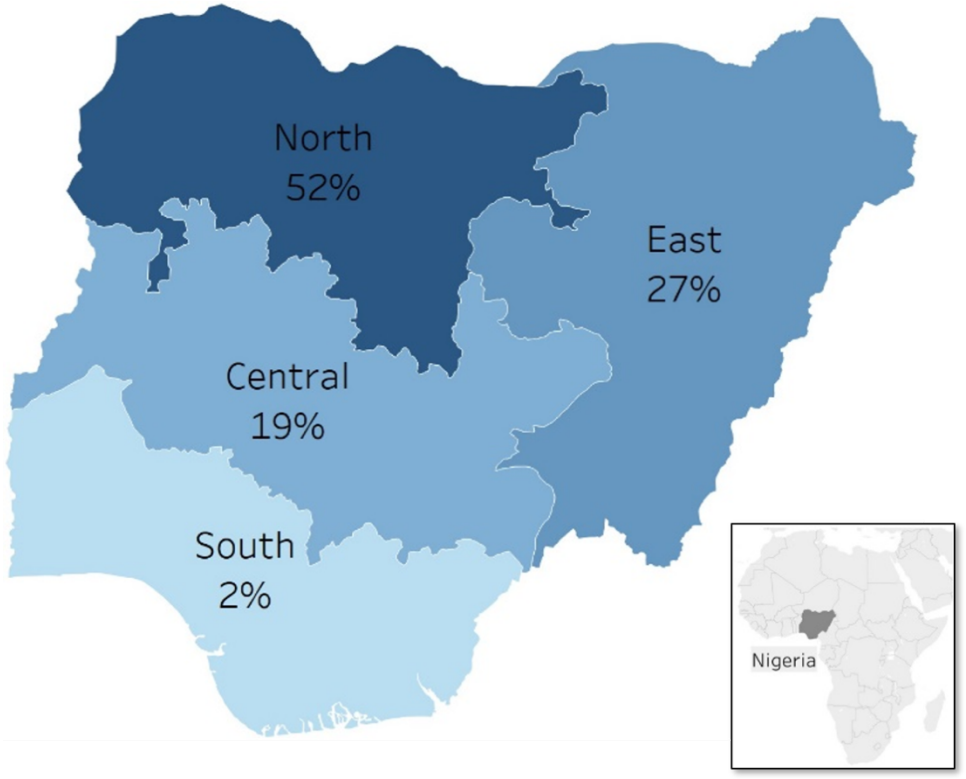

Figure 13: Nigeria map showing cattle distribution by geographical zone (58)

4.5 Dairy production systems in Nigeria

In Nigeria, Milk and dairy products are sourced from 3 major system of farming. Almost 95% of the raw milk produced in the country is sourced from the pastoral system. The agro-pastoral and commercial system amounts for only 5% of raw milk produced in Nigeria (59).

4.5.1 Pastoral

In the pastoral systems, farmers move cattle from place to place in search of pastures and water (60). Herd size ranges from 100 to 300 heads of indigenous breeds. Production is subsistence oriented and animals are kept on uncultivated pastures and rely on grazing without any feed supplements. The herders frequently move their cattle within states and boundaries, hence do not participate in any form of farming or crop cultivation. They are primarily based in the northern part of the country, though some often migrate to the South in search of water and pasture during the dry season (61). Main products include beef, milk, hides, manure and horns. This system is characterised

by low milk productivity: about 0.5-1 litre per cow per day over the lactation period. The cows are milked once a day mostly by women (62). This system is dominant in Northern Nigeria.

4.5.2 Agro-pastoral

In the agro-pastoral systems farmers are engaged in growing crops and raising livestock (59). They keep mainly indigenous breeds, with herd size ranging from 20 to 100 heads. Dairy production's objective can be self-consumption or commercial (63). Family labour is mainly used and the animals rely on grazing on demarcated rangelands and supplementary feeds. This system is present in the southern regions.

4.5.3 Commercial

In commercial systems, dairy animals are raised for maximum milk output and they are kept

indoors in sheds or paddocks. This system consists of established dairy farms which mostly have a mix of indigenous cows, crossbreeds (e.g., mix of local cow with Friesian Holstein breed) and Exotic breeds, with herd size ranging from 50 to 1000 heads (64), and give them high quality feed. Feed comes from cultivated pastures (intensity is in feed production where pastures of high-quality forages are grown). The majority of the commercial dairy farms are located in the North Central region.

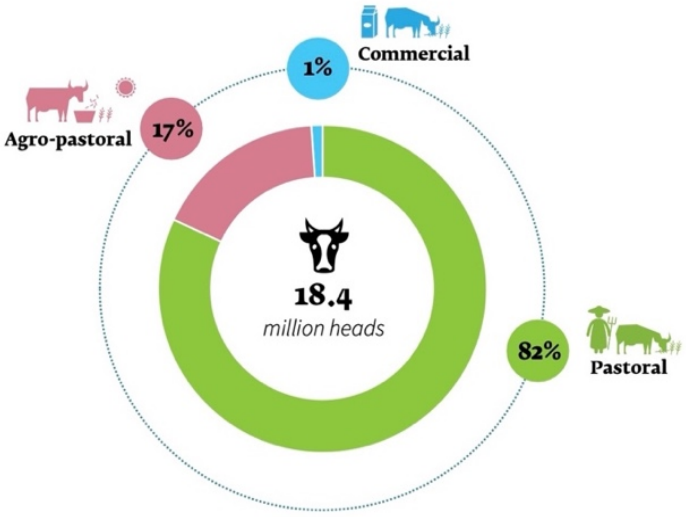

Figure 14: Dairy production systems in Nigeria (59)

4.6 Indigenous cattle breeds of Nigeria

There are many breeds of cattle indigenous to Nigeria; the popular breeds of cattle in Nigeria include;

White Fulani, Sokoto Gudali, Adamawa Gudali, Red Bororo, Wadara, Azawak, Muturu, Keteku, Ndama and Kuri (65).

In this chapter we will be characterizing the three major breed of cattle that contributes to Nigeria's domestic milk production which are all part of the subspecies *Bos indicus* (zebu):

- White Fulani;
- Sokoto Gudali;
- Adamawa Gudali.

4.6.1 White Fulani (Bunaji)

The White Fulani of Nigeria is the most numerous and widespread of all Nigerian cattle breeds, The Nigerian National Livestock Research Survey 2011 (NNLRS) estimated that they represent 37% of the national herd. The White Fulani cattle are mainly owned by the nomadic Fulani people (66), who occupy the northern part in Nigeria. Locally, White Fulani is also called: Bunaji (67).

1.2.1.1 Origin of the white Fulani

The White Fulani were brought to their present locations through the many migrations of the Fulani people over the last 500 years (67). There are several arguments about the true origin of this breed and theories have been postulated to trace the origin of the White Fulani.

There are two schools of thoughts about the origin of the breed. One is that the White Fulani are truly long-horned zebus, and this assumption is due to appearance of a distinct hump in a newborn bull calf, and the characteristic nature of the skull and thoracic vertebra (68).

The other assumption is that they originated from interbreeding the Sanga breed with thoracic humped zebu animals. This interbreeding could have resulted in cattle with lyre-shaped horns including the White Fulani (66).

1.2.1.2 Geographical distribution

This White Fulani cattle are found in almost every part of the country, from Lagos to Sokoto, Katsina and Kano states and spread across the Nigerian Middle Belt (65). The only area from which they are significantly absent is in the south-eastern part of the country, where there are no resident zebu (65).

The climatic environment in the areas in which the White Fulani are predominantly found is tropical and characterized by two well defined seasons, the wet and dry seasons and two prevailing wind systems: the south-west rain bearing wind from the Gulf of Guinea and the dry north-easternly dust-laden wind (the harmattan) (68).

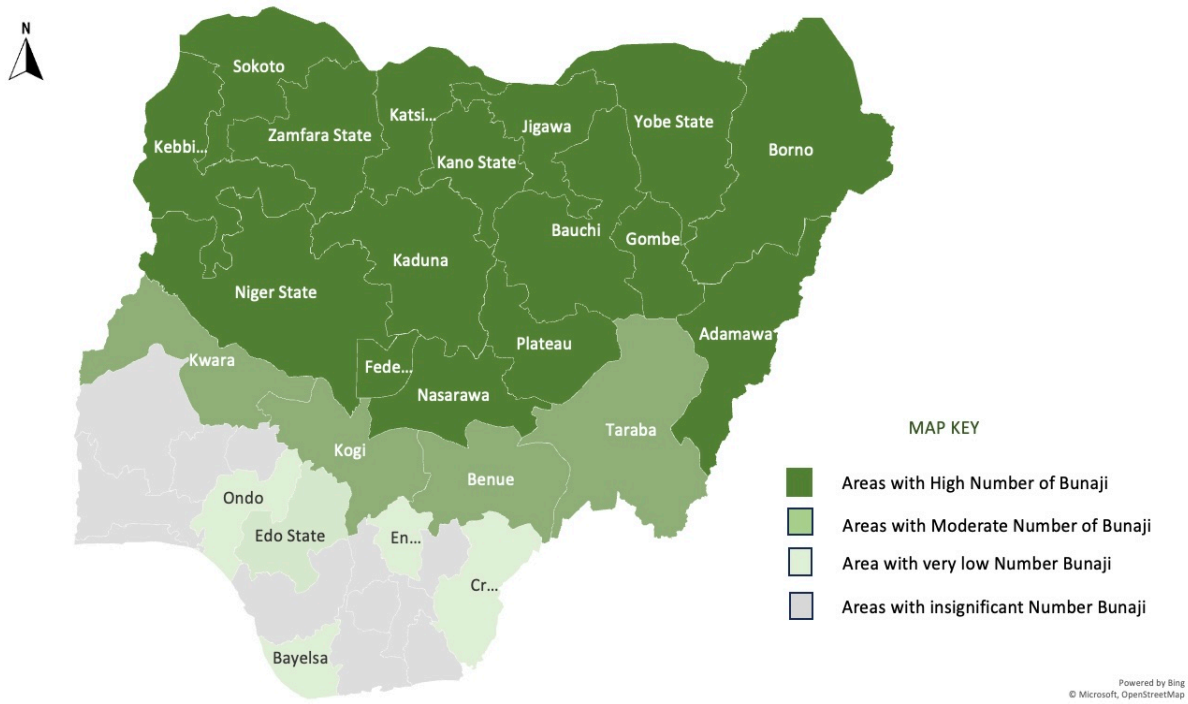

Figure 15: Nigerian map showing the distribution of White Fulani (Bunaji) cattle across the country (65)

1.2.1.3 Physical characteristics

The coat of the White Fulani is commonly white on a black skin with black ears, eyes, muzzle, hooves, horn tips and tip of tail. There are a few cases with black coats mixed with dark flecking, or red and white coats (66).

They are fairly large, with an approximate height about 130cm, the bull weighs about 500 kg and cows 325kg.

The hump is either thoracic or cervico-thoracically located, musculo-fatty in structure. It is well developed more developed in the bulls than in cows (67).

The horns are medium, slender, well-proportioned and carried high on the head. They are also round in cross-section and curve outwards and upwards soon after leaving the head. Most animals have horns with an outward twist at the tips, giving the characteristic lyre shape; horns vary in length from about 81 to 107cm.

The udder of the White Fulani cow is fairly developed and is strongly attached. The teats are well positioned and are of medium to large size (69).

Figure 16: White Fulani (Bunaji) cattle (70)

4.6.2 Sokoto Gudali (Bokolooji)

The word gudali is Hausa language for short-horned, short-legged cattle. There are two quite distinct types of Gudali in Nigeria: Sokoto Gudali (Bokolooji) and Adamawa Gudali. The NNLRS in 2011 estimated that Gudali represents 32% of the national herd. The Sokoto Gudali is also called Bokolooji.

1.2.1.4 Origin of Sokoto Gudali cattle

Gudali is classified in the Sahelian Zebu breeds, and believed to have descended from the Indo-Pakistani Zebu, which entered the Horn of Africa by way of the Persian Gulf and south Arabia. Arabian invaders spread the zebu to the south and west over the continent from 669 BC. It is among the short-horned zebu of the west and Central Africa.

1.2.1.5 Geographical distribution

Although traditionally the Sokoto Gudali occurs mainly in Sokoto State, North-west of Nigeria, realistically it is now distributed widely throughout Nigeria and neighbouring Sahelian countries.

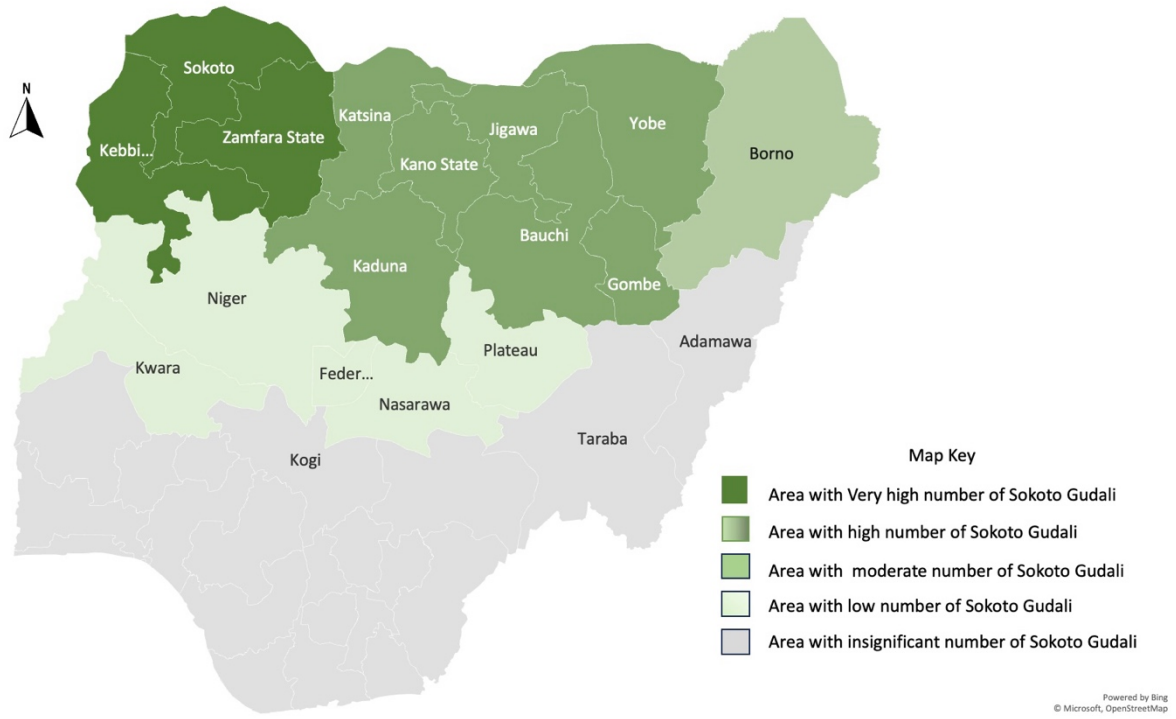

Figure 17: Map of Nigeria showing the distribution of Sokoto Gudali (Bokoloji) cattle across the country (65)

1.2.1.6 Physical characteristics

The coats have a uniform cream colour, light grey or dun, with dark shadings around the face, neck and hind quarter, the coat is short and the skin is thick and pigmented.

The dewlap, skin folds and naval flab are very well developed, large and very prominent in both genders.

In the Sokoto Gudali horns are very short; a bit longer in cows than in bulls, the horns effectively absent in some cases.

Upper thighs are of fair width, but tend to narrow somewhat down, the tail is long and well developed, terminating with a switch almost touching the ground, and ears are long, large and convex and pendulous (65).

The hump is rounded from front to back with a slight fall at the back, firmly placed over the withers (thoracic in position) and Musculo-fatty in structure, especially in the bulls.

The average height at withers ranges from 130-138 cm for males and 116-132 cm for females. Mature weights range from 495-660 kg for males and 240-355 kg for females.

Figure 18: Sokoto Gudalo (Bokoloji) cattle (71)

4.6.3 Adamawa Gudali

The NNLRS in 2011 estimated that Adamawa Gudali represented 2% of the national herd. At least two local types were originally recognized in Nigeria: the Banyo, with Rahaji blood, and the Yola, which had an admixture of Muturu. The Adamawa Gudali, as its name implies, is restricted to Adamawa state north east Nigeria, and some neighbouring states in the region (72)

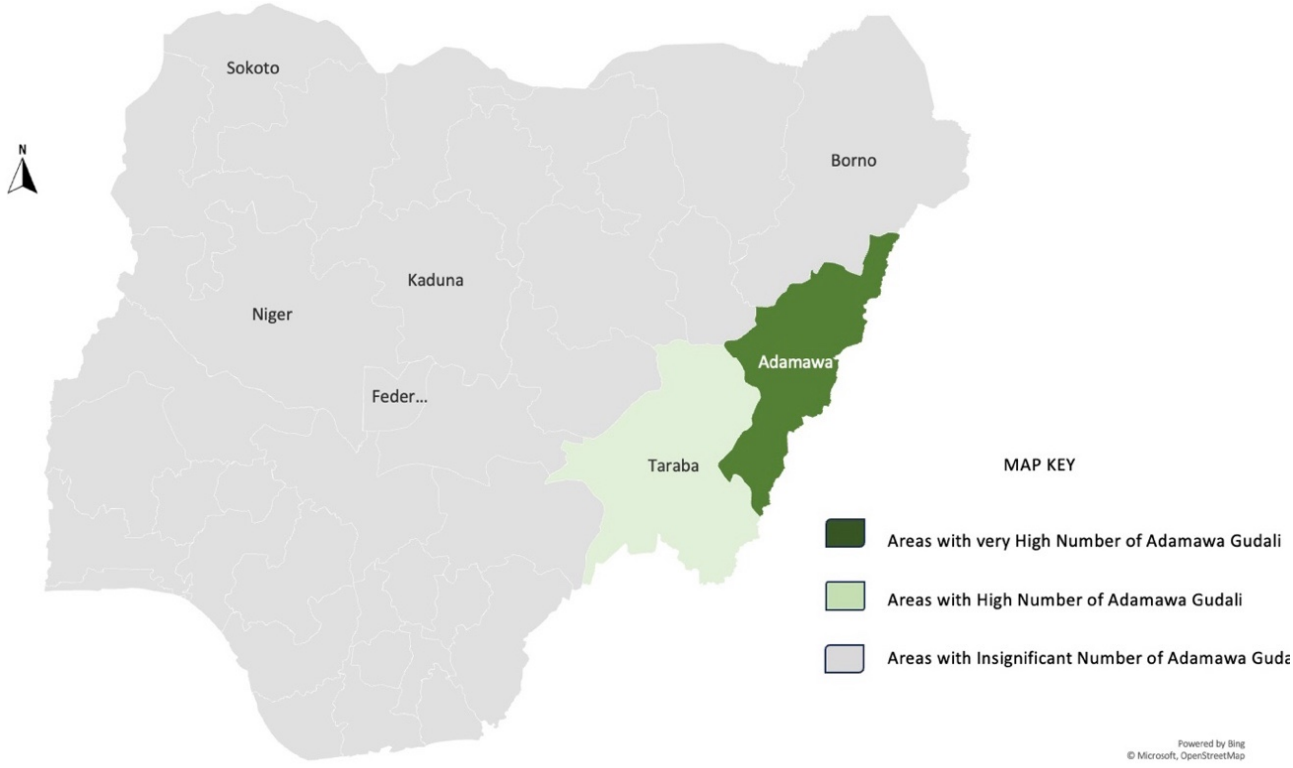

Figure 19: Map of Nigeria showing the distribution of Adama Gudali cattle (72)

1.2.1.7 Physical characteristic

Adamawa Gudali resembles the Bunaji in conformation; they are shorter and small-bodied. The coat has a mixture of red, black, brown, blue and white, with the white either in patches or speckles. The coat is short and the skin is thick and pigmented.

Dewlap, skin folds and naval folds vary from being small and poorly developed to moderately well developed.

In the Adamawa Gudali, horns short to medium in length, moderate in size/thickness and projecting outwards upwards and slightly forward; crescent shape. The ears are large and pendulous similar to that of the Sokoto Gudali.

Hump is very large and pendulous, generally hanging over on one side and having the appearance of being broken. It is thoracic in position and musclo-fatty in structure as in Sokoto Gudali; it is shaped like a conical hat in the bulls (65).

Figure 20: Adamawa Gudali cattle (71)

Table 6: Production characteristics of White Fulani, Sokoto Gudali and Adamawa Gudali cattle breeds (69,73)

Character	White Fulani	Sokoto Gudali	Adamawa Gudali
Heifer maturity age (Years)	1.7-2.2	2.5-4.0	2.5-3.0
Age at first calving (Years)	3.3-4.0	3.5-4.0	2.5-4.0
Calving interval (Days)	408	398	395
Cow production lifespan (Years)	13-15	13-15	12-14
Number of calves produced (lifetime)	6	6-7	5-6
Lactation length (Days)	204.13	216.32	204
Dry period length (Days)	129.86	104.80	126
Daily milk yield (Hand milking (L)	1.08	1.75	1.58
Daily milk yield (Machine milking (L)	-	-	-
Lactation yield (L)	195	321	302.6

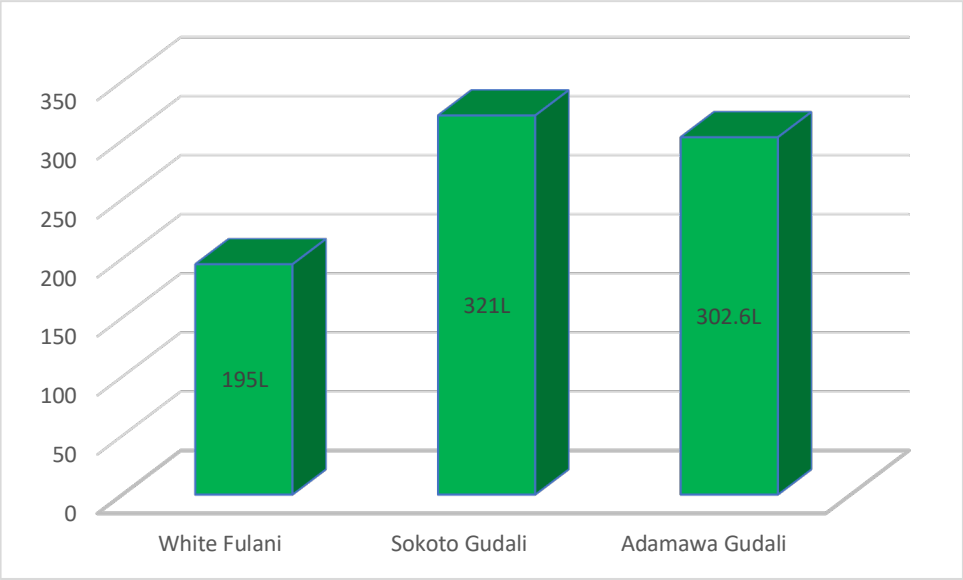

Figure 21: Graph showing the lactation yield of the three breeds.*S*

4.7 Factors limiting milk production in Nigeria

The Nigerian dairy sector has a number of obstacles that have restricted the production of milk and dairy products as well as marketing milk. These limiting factors include:

Insecurity: Over the years Nigeria has faced and still facing a series of security challenges across the country. The issue of insecurity had negatively impacted the economy of Nigeria. Livestock farming is also a crucial economic activity in the northwest, and the involvement of bandits has led to the rustling of cattle and other

livestock. This not only results in economic losses for herders but also disrupts meat and dairy products supply chain (74). Domestic milk output or production has been on constant decline over the years. This latter has made the milk production or the dairy sector unattractive for both local and international investors.

Neglect of grazing routes: In the 1950s, ways were carved out for cattle grazing to ease movement of cattle by herders/Pastoralist across the country. However, several investigations has revealed that the grazing routes have been taken over, over the years, by modern facilities built for the public good (75). This has forced cattle herders to use alternative routes in other to move from one part of the country to the other, leading lots of farmers- herder conflicts and clashes, as the pastoralist encroach on land cultivated by crop-farmers while in search of pasture. This has mad milk production more difficult among pastoral farmers, thereby significantly hindering the milk sector of the country.

Milk collection and processing method: Due to the fact that majority of milk producing cows in the country are owned by pastoralist that do not have access to electricity or technology for machine milking, milk collection is usually done manually which is a less effective method of milk collection. Hand milking has made it very difficult to attain the peak milk yield per cows. This milking technique only allow for the harvest of 20-40% of milk which is stored in the cisternal cavity close to the teats (76).

Obsolete cattle rearing practice: It had been reported that Nigeria produces millions of animals a year and these animals are usually raised by herders using the free-range/open grazing system. Open grazing in Nigeria has been an age-long practice associated with the people of the Sahel (77).

The open grazing practice of roaming about with animals including the human beings who pilot and guide their ways through the grazing routes in any open fields, plains and nearby bushes in search of pasture, food, water and shelter for the animals, sometimes animals move for long duration of time before coming across a suitable pasture and may as well spend days without coming across water source. Stress on animals and impossibly for herders to control the quality of plants or food ingested by their animals reduces the quality and quantity of milk produced (78).

The cattle breeds used; Majority of the milk produced in Nigeria is derived from local indigenous breeds, mostly owned by pastoralist. These breeds of cattle are characterized by a low milk yield due to the production system used (79).

Environmental factors: Climatic variables including temperature, rainfall, and relative humidity have negatively impacted milk production both in the long and short run. Heat stress brought on by a rise in temperature causes dairy cows to consume less dry matter, which lowers milk quality and output. Prolonged droughts have a negative effect on the production of dairy milk. Increased prevalence of diseases brought on by excessive rain damage the animals' health and result in a sharp decline in milk output. Low milk quality and quantity are caused by dairy cows' increased microbial activity when relative humidity is high (80).

Neglect of agricultural sector by the government: In the Nigerian agricultural sector, livestock production started suffering neglect from the 1970s as a result of the oil boom (81). Lately, various attempts have been made to facilitate the performance of the agricultural sector, the federal and state governments of Nigeria under different policy regimes have intervened through some agricultural policies and programs. Meanwhile these policies have not helped much in improving significantly the agricultural sector (82). In the dairy production sector, there are currently no governmental policies that are aimed at boosting the sector.

Other factors: Low level of literacy among the dairy farmers and the pastoralists, Insufficient basic amenities and infrastructures, in adequate dairy knowledge and poor farm management skills, unhygienic milk collection and processing practices, and inadequate extension services, poor access to dairy markets in many rural areas, non-existence of dairy cooperative union, short of extension agencies, lack of milk collection centre infrastructures and processing facilities close to the dairy farmers, high cost of artificial insemination and animal health services amongst others have all together contributed in hindering milk production in Nigeria (74).

Conclusion and recommendations

The study comprehensively analyses the constraints and challenges facing milk production in Nigeria, identifying key factors such as traditional cattle rearing practices, environmental impacts, and socio-economic issues. Pastoral systems dominate the dairy sector, yet they are characterized by low productivity due to inefficient hand-milking techniques, reliance on indigenous cattle breeds with inherently low milk yield, and the impacts of climate variability.

Key obstacles include:

1. **Inefficient milking techniques**: the predominant use of manual hand-milking significantly limits milk yield, capturing only 20-40% of the cows' potential production;
2. **Traditional cattle rearing practices**: the open grazing system exposes cattle to stress, uncontrolled feeding, and long durations without water, reducing milk quantity and quality;
3. **Environmental factors**: climatic conditions such as heat stress, drought, and excessive rainfall adversely affect dairy production by reducing feed intake and increasing disease prevalence;
4. **Socio-economic and infrastructural deficiencies**: lack of access to technology, education, and basic amenities, coupled with inadequate government policies and support hampers the development of the dairy sector.

Addressing these issues requires a multifaceted approach. Investment in modern dairy farming techniques, improved breeds, climate-smart agricultural practices, and supportive infrastructure is essential. Furthermore, enhancing government policies to support dairy farmers and integrating educational programs can empower pastoralists, leading to improved productivity and sustainability in the Nigerian dairy sector.

Future research should focus on the implementation and impact of these recommended strategies, assessing their effectiveness in transforming Nigeria's dairy industry and contributing to broader agricultural and economic development.

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Summary

Introduction

The introduction discusses the importance of food self-sufficiency, particularly in milk production, for modern economies. Despite having many cows, Africa, including Nigeria, struggles to produce enough milk for its needs. Milk is vital for nutrition and economic sustainability. The study focuses on the Nigerian dairy sector, examining cattle breeds, production systems, and socio-economic and environmental factors affecting milk production. It aims to identify strategies to enhance productivity and sustainability, offering insights for policymakers, stakeholders, and researchers. The introduction outlines the structure of the study, covering milk production, factors influencing it, and dairy cattle breeds, along with Nigeria's geographical and climatic conditions, cattle demographics, and production systems.

Milk and milk production

Milk is commercially defined as the lacteal secretion from healthy cows, excluding colostrum, with a minimum content of 8.25% milk solids not fat and 3.25% milk fat. It is a white liquid produced by the mammary glands of mammals, intended for feeding their offspring. The complexity of milk is highlighted by its composition, which includes principal constituents like water, lipids, carbohydrates (primarily lactose), and proteins. Additionally, it contains numerous minor constituents such as minerals, vitamins, hormones, and enzymes, with water comprising 85-87%, fats 3.8-5.5%, proteins 2.9-4.0%, and carbohydrates around 5%.

The production of milk involves a series of processes: synthesis, secretion, ejection, and removal. The mammary gland synthesizes milk from blood-derived precursors, capturing essential nutrients through its secretory epithelium. The process is influenced by factors such as the frequency of milking and overall lactation management. Anatomically, the mammary gland's structure, including alveoli and ducts, plays a crucial role in milk synthesis and secretion. Milk stored within the gland can be removed either by suckling or milking, with the distribution between alveolar milk (in alveoli and small ducts) and cistern milk (in larger ducts and cisterns) being key to maintaining lactation.

The chapter also discusses the lactation curve, which represents milk production over the lactation cycle. This curve peaks shortly after calving and then gradually declines

until the cow's milk supply dries up. Understanding the lactation curve is essential for evaluating important milk production characteristics such as maximum yield and persistency. Overall, Chapter 1 provides a comprehensive overview of the physiological, biochemical, and anatomical aspects of milk production, emphasizing the factors that influence milk yield and composition.

Factors influencing milk production

The factors influencing milk production in dairy cattle are categorized into several groups: genetic, physiological, environmental, biological, and management factors. Each of these factors plays a significant role in determining the quantity and quality of milk produced by dairy cows.

Genetic factors include breed variations, which are pivotal in setting the potential for milk production. Breeds specialized in milk production, such as Frisian and Holstein, exhibit higher yields compared to those bred for mixed or meat production. Additionally, individual cows within the same breed can show considerable differences in milk yield due to genetic variations.

Physiological factors are crucial, with age at first calving and lactation number being particularly influential. Milk production generally increases with the cow's age and peaks around the third or fourth lactation before it starts to decline. The gestation period also negatively impacts milk yield, especially after the fifth month due to hormonal changes that inhibit milk secretion.

Environmental factors such as the season of calving significantly affect milk production. Cows calving in late fall to spring tend to produce more milk compared to those calving in summer, due to better climatic conditions and feed availability. Additionally, photoperiod, or the duration of light exposure, affects mammary gland development and milk yield.

Biological factors, including diseases like mastitis, can substantially reduce milk production. Mastitis, in particular, impairs milk synthesis and destroys secretory tissues, leading to a prolonged decrease in milk yield even after recovery.

Management factors encompass practices such as the length of the dry period. A standard dry period of 42 to 60 days is recommended to allow mammary tissue regeneration and maximize milk production in subsequent lactations. Extending the dry period beyond this range offers minimal benefits and is economically unjustified.

Dairy cattle breeds

Dairy cattle have been specifically selected and bred over many years to enhance milk production, unlike other livestock, which may also be used for meat or draught purposes. This selective breeding has led to the development of several prominent dairy breeds, each with distinct characteristics and origins.

The chapter discusses various major dairy breeds in the world, including Ayrshire, Brown Swiss, Guernsey, Holstein, Jersey, and Normande. All these breeds belong to the Bos taurus species and have undergone significant selection for increased milk production over recent decades.

Ayrshire cattle, originating from Ayr in Scotland, are known for their red and white color and balanced udders, with a high milk production potential of 19-27 liters per day and an average yield of about 7000 liters per lactation.

Brown Swiss cattle, one of the oldest dairy breeds, originating from Switzerland, are noted for their dark brown color and high protein and total solids content in their milk, producing between 21-29 liters per day.

Guernsey cattle, from the island of Guernsey, are efficient converters of feed to product, producing 18-26 liters of milk per day with moderate butterfat content. They reach reproductive maturity early and can calve at 22 months of age.

Holstein cattle, originating from the Netherlands, are known for their high milk production and have been selectively bred to utilize the area's abundant grass resources efficiently. Holsteins are used for dairy purposes in over 150 countries due to their hearty and efficient nature.

Analysis and data review of Nigera

This chapter provides a comprehensive analysis of dairy production systems in Nigeria, focusing on the pastoral, agro-pastoral, and commercial systems. Each system is characterized by distinct features, management practices, and socio-economic impacts.

The pastoral system, predominant in northern Nigeria, involves herders moving cattle in search of pastures and water. Herd sizes range from 100 to 300 heads, and production is mainly subsistence-oriented, relying on grazing without feed supplements. Milk productivity is low, averaging 0.5 to 1 liter per cow per day, with cows milked once daily, predominantly by women. This system contributes approximately 95% of Nigeria's raw milk production.

In contrast, the agro-pastoral system combines crop farming and livestock rearing, mainly in southern Nigeria. Farmers maintain herd sizes of 20 to 100 heads, primarily indigenous breeds. Dairy production here can be for self-consumption or commercial purposes, with family labor being the main workforce. Animals graze on demarcated rangelands with supplementary feeds. This system accounts for a smaller proportion of the country's raw milk production.

The commercial system is characterized by established dairy farms aiming for maximum milk output, using a mix of indigenous, crossbred, and exotic breeds. Herd sizes range from 50 to 1000 heads, with animals kept indoors in sheds or paddocks. These farms rely heavily on high-quality feed from cultivated pastures and are primarily located in the North Central region. This system, although less common, plays a significant role in enhancing milk production efficiency and sustainability in Nigeria.

Additionally, the chapter delves into the indigenous cattle breeds of Nigeria, highlighting the White Fulani, Sokoto Gudali, and Adamawa Gudali breeds, which are crucial for the country's domestic milk production. The White Fulani, also known as Bunaji, is the most numerous and widespread breed, representing 37% of the national herd. These cattle are mainly owned by the nomadic Fulani people in northern Nigeria. The Sokoto Gudali and Adamawa Gudali breeds are also significant, with unique characteristics and contributions to milk production.

Several factors negatively impact dairy production in Nigeria. Environmental challenges such as heat stress, prolonged droughts, and high humidity affect milk quality and output. Additionally, the neglect of the agricultural sector due to the oil boom since the 1970s, coupled with inadequate governmental policies to support dairy farming, has hindered the sector's growth. Other contributing factors include low literacy levels among farmers, insufficient infrastructure, poor farm management skills, unhygienic milk collection practices, and lack of access to markets and extension services.

Conclusion and recommendation

Summarizes the constraints and challenges in Nigeria's dairy sector, such as inefficient milking techniques, traditional rearing practices, climatic impacts, and infrastructural deficiencies.

Proposes recommendations to address these challenges, including sustainable breeding, improved husbandry practices, and supportive policies to enhance milk production in Nigeria.

This comprehensive study provides valuable insights into the potential of Nigerian cattle breeds for milk production and outlines practical solutions to improve the country's dairy industry.