



SUSTAINABLE DAIRY DEVELOPMENT: A PANACEA TO FOOD INSECURITY IN NIGERIA (A REVIEW)



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Abstract:

Promoting sustainable dairy development by the government and all concerned stakeholders in any agrarian society is one of the gateways to ensuring food security. In Africa especially Nigeria, breeding and grazing of animals for meat and milk production have resulted in the availability of nutritious foods and provision of dietary protein for the growing populace. This review aims at addressing the current situation of Nigeria's dairy sector and also identify how sustainable dairy production and development can contribute significantly to food security. Many factors have greatly contributed to the challenges ravaging Nigeria's dairy sector, this includes poor nutrition, conflicts between farmers and herders, climate change, limited availability of cold chain infrastructure for transporting milk, unhygienic milk collection practice and inadequate extension services, amongst others. To achieve sustainable dairy production in Nigeria, measures that will result in improved milk quality, development of value-added milk products, and increased animal productivity must be urgently addressed. Reinforcement and implementation of the existing government policies on the availability of suitable and adequate food supply to the citizenry, laws that will support animal grazing without causing any harm to the residents, and application of smart and modern dairy farming technologies are promising solutions to boosting sustainable dairy development in Nigeria.

Keywords:

Food security; Africa; Dairy; Sustainable; Herders; Climate change; Conflicts.

Introduction

Food insecurity in Nigeria especially among children is at an alarming rate, accounting for about 25 million undernourished and stunted children, ranking Nigeria as number one in Africa and the second largest in the world where malnutrition is prevalent (UNICEF, 2022). Around 2 billion people, or nearly one-third of the world's population, suffer from micronutrient malnutrition (also known as hidden hunger), which includes deficiencies in vitamins A, iron, iodine, zinc, and other essential nutrients (Ohanenye *et al.*, 2021). In addition to diet-related chronic disorders, antibiotic resistance, foodborne pathogens, pesticide residues and

contaminations from chemicals, have posed a threat to nutrition security (Schlundt *et al.*, 2020). Concerns regarding food security have gained priority in the 20th century, food security issues have been a crucial concept to government and relevant stakeholders during policies and decision-making processes.

Drinking milk for healthy living will certainly boost immunity, and fight malnutrition and micronutrient deficiencies which are prevalent among many in Nigeria and other developing countries in Africa (Yusuf and Obaghwarhievwo, 2021). The dairy industry in Nigeria has a major role in the Nigerian agricultural sector because of the nutritional fact that is derived from milk, and this milk especially from cows serves as an important source of nutrients essential for the proper growth, development, and functioning of the human body at every stage of growth and developments (from infancy to adulthood). Consumption of milk and dairy products is important to human health as it supplies a sustainable amount of nutrients like vitamins, protein, magnesium, and calcium to the body (FAO, 2019). Nigeria's dairy consumption is rising faster than the rate of its production and has resulted in the importation of milk from other countries (Adewumi *et al.*, 2015). Nigeria's population is estimated to be approximately 220 million ranking Nigeria as the most

populous country in Africa, this figure is projected to increase to about 401.31 million by the last quarter of 2050, this growing population signifies an increase in demand for milk and milk products as milk consumption is projected to reach 4.2 million tonnes in the year 2050, growing by 262% (FAO, 2019).

The Nigeria milk industry - dairy value chain performs activities such as dairy production, processing, marketing, importation, and consumption. However, these activities have truly not been in the limelight despite several efforts by the government and non-governmental organizations. The Nigeria dairy value chain consists of a larger percentage of pastoralists and accounts for about 95% of the dairy output. Raw milk is processed into other dairy products

i.e.; *wara*, *nunu*, *kindirmo*, *manshanu*, and *cuku*, on a small scale and sold informally on the streets for household consumption by the processors. Various forms of dairy products are sold in the formal market using a combination of imported and locally produced milk. Because of the limited amount of milk produced by the pastoralists, a huge amount of milk inputs used by commercial processors is imported (Yilma *et al.*, 2011).

There are large herds of indigenous cattle most especially in the Northern part of Nigeria, the herders practice the act of land and crop residue grazing, and raw milk and other dairy products are sold locally in the community markets. Most of the commercial dairy farms which contribute less than 10% of the total output are situated in the central region. The majority of cattle in Nigeria are found in the North. Most of these cows are local breeds (99%), while less than 1% are imported from the Netherlands and South Africa (Asresie and Zemedu, 2015). In the Northern part of Nigeria where the predominance of the cattle population is greater than 50% (Figure 1), rearing of cattle and dairy farming has greatly contributed significantly to household welfare and is a veritable source of livelihood to many in this region.

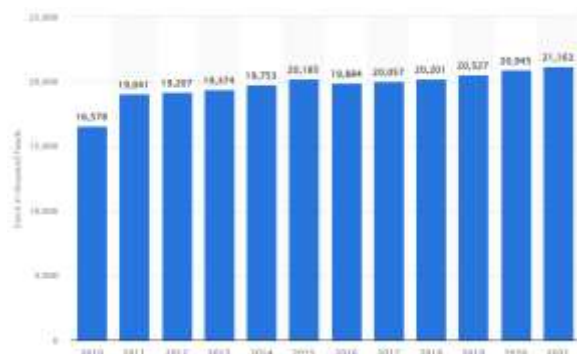


Figure 1: Stock of live cattle in Nigeria from 2010 to 2021 (in 1,000 heads) (Sasu, 2023) Nigeria's milk and dairy products are derived from these four major farming systems:

The settled Fulani pastoral system: The farmer/herder keeps up to 100 herds of animals in this system and cultivates some crops at the same time. The areas used to graze the animals are recently-harvested areas and fallow ground. Cows are only milked once a day (Lopez-Villalobos *et al.*, 2023). It has been reported that a lot of the settled Fulani cattle herders stayed in their villages for 20 years or more.

The non-settled Fulani nomadic system: In this type of nomadic cattle-rearing system, cattle are moved from one state to another in search of food and water (Olawepo, 2021). The nomadic system has an impact on the nutrition and management of animals. The herders do not participate in any farming or cultivation of crops but frequently move their cattle within states and boundaries. Most of the dry season feeding of the cattle is done on fallows as well as on the fields of the farmers. During the dry season, as the water levels go down, they migrate to the river basin, to obtain sufficient water (Partey *et al.*, 2017).

Smallholder dairy farming: Smallholder dairy farming contributes to household resilience, food, and nutrition security and also serves as veritable income for rural household dwellers (Ugwu, 2010).

Large-scale dairy farming: Large-scale dairy farming is characterized by large herds (more than 100 dairy cows) as well as rearing their heifer replacements, zero grazing, heavy mechanization, heat stress, and artificial insemination. They have all activities in one location some of which include the production of feed, and raw milk, cattle management, and processing infrastructure and factories (Brito *et al.*, 2021).

Nigeria's dairy development and domestic milk production

The dairy industry was the source of income for approximately 183 thousand rural households dating back to 1986 (FAO, 1988). The dairy industry provides employment and serves as the source of income generation through commercialized milk processing plants and marketing initiatives. However up to date, despite having 63 known milk processing plants, very few of these plants are still functional. Those that still run processing activities function at less than 20

% of their capacity. It is also noted that the Nigerian dairy industry has been overridden by other foreign milk processing firms that rely heavily on imported milk powder to manufacture and sell milk and dairy products. In 1962 - 1968 and 1981 -1985, many national development plans evolved through the effort of the Nigerian government and thus improved the standards and the living conditions of every citizenry, during this

period attention was given to the dairy industries since it held and still holds the potential of improving nutrition. The government established dairy farms with both native and foreign breeds of cattle in selected locations across the states.

Also, mobile collection locations and milk collection units were set up. The milk collection programs kickstarted in the late 1920s when the veterinary department, Vom, Jos, was backed up by the Northern region government of Nigeria and established these units in Northern Nigeria. Milk was delivered to the milk collection units by wives of the pastoralists for cream separation and clarified butter fat (CBF) production. Consequently, in 1939, the veterinary department in Vom (Jos-Plateau) established a milk processing plant with a spotlight on butter production. The factory's major source of milk was from the Fulani women through a network of milk collection centers, and milk was also obtained from the Vom dairy. In 1940, a similar initiative was set in motion in Kano state.

Nigeria has the fifth largest cattle population in Africa following Ethiopia, Sudan, Chad, and Tanzania, with an estimated 20.5 million cattle, which include 2.35 million dairy cows, (where 99% of these cattle are indigenous breeds) have accounting for over 90% of the total annual milk production, milk from these cattle is low input, low yielding pastoral systems and traded many in an informal value chain system (NASS, 2010). It is imperative to note that Nigeria

must increase its dairy domestic production because of the country's growing population and demand for dairy products every day (FAO, 2019). The dairy import control policy in Nigeria has been ineffective and Nigeria spends a lot of foreign exchange on dairy imports yearly. Nigeria has a population of over 180 million and consumes 1.3 million tonnes of milk annually. Unfortunately, 60% of dairy products are imported and consumed. According to the Central Bank of Nigeria (CBN), Nigeria imports milk and dairy products worth \$1.5 billion annually.

The establishment of the Nigerian Dairy Development Programme (NDDP) by the Federal Government, aimed at strengthening the dairy transformation agenda of the Federal Government of Nigeria by demonstrating proof-of-scale in Nigeria's processor-led initiatives for dairy development. NNDP programme help to improve the livelihoods of participating dairy farmers in Nigeria by increasing the output and productivity of their cattle and integrating them into the formal dairy value chain. The programme also includes a nutrition and a gender component geared towards improving nutrition outcomes and empowering women in smallholder farming communities.

Recently, the Nigerian dairy industry has seen some significant developments, including the launch of government initiatives such as the National Livestock Transformation Program (NLTP). The National Livestock Transformation Program (NLTP) reported that Nigeria produces 526,000 litres of milk annually, whereas 1.2 million litres are consumed yearly. Almost \$1.3 billion is spent on importing milk every year. Some government and non-governmental established parastatals who have contributed to the growth of the dairy industry in Nigeria include; Vom Dairy (Plateau State), Shonga Dairies (Kwara State), back-to-farm project initiated by the Kwara State government, National Project for Cattle and Buffalo Breeding (NPCBB), Agege Dairy Development Project (Agege,

Lagos), Moor Plantation Dairy Farm (Ibadan), Intensive Dairy Development Programme (IDDP), Strengthening Infrastructure

for Quality and Clean Milk Production (SIQ and CMP), Cooperatives Union, National Programme for Dairy Development (NPDD), United African Company (UAC), Friesland Campina WAMCO, New Zealand, Arla foods, Neon Agro., Chi Limited, Irish Dairy, etc.

In the last few decades, the Nigerian dairy market has been mostly controlled by European dairy organizations which include Friesland Campina WAMCO, Arla, PZ Wilmar, and Fan Milk, while many of these dairy processing company relies on milk imports for the production of their products. However, Friesland Campina WAMCO is one of the few multinational companies that source raw milk locally. The raw milk of the cows of Integrated Dairy, L&Z Integrated farms, and Nagari farms are also procured from pastoralists and peri-urban farmers.

In 2010, Friesland Campina WAMCO, Nigeria was the first to source raw milk locally for the manufacturing of varieties of milk and dairy products, herders supply the majority of the raw materials that are used for the manufacturing of various milk and dairy products. Through their dairy development initiative, they developed the local farmers in 3 ways; increasing productivity per cow, raising raw milk quality and safety, and supporting farmers in getting a market for their milk. Friesland Campina WAMCO has assisted in raising the livelihood of many and supported farmers in the provision of basic infrastructures, genetic improvement activities via artificial insemination and cross-breeding, establishing smallholder dairy farms, and building of demonstration farms, pasture and fodder developments for animals, all located in different states of the country (FCWAMCO, 2021)

Friesland Campina has tremendously boosted Nigeria's local milk sourcing by establishing milk collection centers across states in Nigeria; 1 milk bulking center, 7 milk collection centers and 20 milk collection points, they are the largest importer and processor of milk products in Nigeria. In 2022, it was reported that 10% of the 60 million liters of raw milk the company uses would be domestically sourced in the next couple of years at a comparable price to the world market price. Friesland Campina WAMCO food company has successfully partnered with the Federal Ministry of Agriculture and Rural Development, Ministry of Trade and Industry, Central Bank of Nigeria, many State Governments, the National Animal Production Research Institute, the Dutch Government, etc. They have assisted the pastoralists in the provision of temperature-controlled milking cans, and 80 solar boreholes across the states. They have also assisted in the establishment of 23 dairy cooperatives (15 locations in Oyo State, 3 locations in Ogun State, 5 locations in Oyo State, 1 location in Niger State, 2 locations in Kwara State, and 1 location in Ondo State) (Langat, 2022). The dairy cooperative union have assisted in the policy-making process and elimination of middlemen in the dairy value chain, which makes it easier to regulate the market's prices. To make up for the shortfall in local output, between \$1.2 billion and \$1.5 billion is spent by the country annually on milk and dairy imports according to the Central Bank of Nigeria (CBN). In July 2019, the governor of the central bank (Godwin Emefiele) suggested the backward integration approach in the sourcing of raw materials which will greatly attract investors and also increase investments in the dairy

sector and at the same time discourage the importation of milk.

Factors affecting smallholder dairy farmers in Nigeria

In Nigeria, marketed milk supplies are from three sources: indigenous Fulani pastoralists, government dairies, and private milk reconstituting plants. As a result of a poor and unhygienic milk collection system by the former, about 90% of the fresh milk produced by the Fulani herdsman does not find its way into the milk processing plants. Consequently, the market for traditionally produced fresh milk is highly localized with surplus milk being sold directly to consumers as fresh milk or processed into several dairy products such as *nunu* (sour milk), *kindirmo* (sour yoghurt), *manshanu* (local butter), *cuku* (Fulani cheese) and *wara* (Yoruba cheese). Some government milk processing plants get part of their fresh milk supply from government dairies and some collect milk from local producers.

About 95 % of the cattle population in Nigeria is owned by the nomads who migrate from the North down to the South in search of water and forage during seasons of scarcity. In the Nigeria dairy sector, there are several challenges that has limited dairy and milk production and the commercialization of milk, some of these factors includes; heightened level of insecurity across the country has made the sector unattractive for heavy local investment, seasonal feed shortages (limited access to water, quality forage and affordable supplemental feed resulting in farmer- herder conflicts, as the pastoralist encroach on land cultivated by crop-farmers while in search of pasture), huge variation in the quality of milk supply, low level of literacy among the dairy farmers and the pastoralists, lack of basic amenities and infrastructures, environmental factors; climate change, heat stress, increasing frequency of drought, unsuitable genetics of local breeds for milk production, limited availability of cold chain infrastructure for transporting milk, lack of 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, lack of extension agencies, lack of milk collection center infrastructures and processing facilities close to the dairy farmers, high cost of artificial insemination and animal health services amongst others. In a survey in 2020 that investigated dairy production practices at pastoral settlements in some selected states of North Eastern Nigeria (Adamawa and Taraba) comprising about 20 local government areas of the two States, it was reported that the unavailability of enough extension agents who may serve as guidance in improving the dairy practices and activities and non-membership of cooperative societies by pastoralists due to non-existence of these cooperative societies were some of the constraints faced by the pastoralist settlements (Adamu *et al.*, 2020).

Climate change has a huge impact on livestock health. It is linked to the life cycle, incidence, spread and the negative effects of livestock diseases (Rowlinson, 2008; Black and Nunn, 2009; IFAD, 2009). Climatic changes like extreme rainfall, flood increased temperatures, drought, and irrigation caused by activities such as bush burning, deforestation and forest fires negatively affect the supply of dairy sector which is a great threat to human health. The plant growth process is impaired by extreme rainfall, increased carbon dioxide concentration and temperature, these retardates the physiological growth,

metabolic activities and productivity of dairy animals grazed in arid regions due to increased NDF (neutral detergent fibre) in their nutrition (Golla, 2021). The changes decrease the rate of water supply and nutritious fodder consumption by the animals which impaired the value chain of production of dairy products such as; milk, meat and eggs. Inadequate water causes appetite and weight loss while the unavailability of quality fodder reduces the energy in animals leading to a high mortality rate. (Babinszky *et al.*, 2011).

Global temperatures have become warmer over the years and tend to increase the level of heat stress on dairy cows, especially in tropical countries (Liu *et al.*, 2017). Heat stress has been reported to cause a decline in milk production, and change the constitution of milk by reducing the total fat and total protein content of the milk (Bernabucci *et al.*, 1999). Other than heat stress, milk production has been reported to be influenced by other factors such as breed, genetic constitution, feed and feeding, housing system, age, season, and agro-ecological zones (Boro *et al.*, 2016; Nayeri *et al.*, 2016; Silpa *et al.*, 2021). These factors can be re-categorized into genotype and environment interactions (G + E). It is noteworthy to state that the genetic component of a dairy cow interacts with the environmental components (G + E) and there are variations in the impact of these interactions. This type of interaction occurs when different environments influence the different genetic makeup of the animals. For example, over the years, the import of high-performing dairy cows from the temperate regions to the tropical regions have had little success as these cows failed to perform in the tropical environment (Berman, 2011).

The majority of milk consumed in Nigeria's rural and urban areas is produced by pastoral groups that can move from state to state. The pastoralist herders are mostly the Fulanis. Since they began migrating to Nigeria from other parts of Western Africa in about the 15th century, the Fulanis were seen as settlers by other ethnic groups. Some of them relocated to the south where they blended with the indigenous Hausa population. After founding an Islamic Caliphate in today's Northern Nigeria and becoming politically more effective, the Fulbe Adamawa, Fulbe Sokoto, Fulbe Mbororo, Fulbe Gombe, and the Fulbe Borgu are the principal Fulani subgroups officially recognized in Nigeria (Babatunde, 2018). Due to climate change and the search for new grazing areas, the nomadic Fulanis and cattle herders are forced to migrate southwards where they compete for land and other farming resources with crop farmers.

Conflicts arose due to the devastation of vast tracts of arable farmland, the rape of non-Fulani women by herders, and cattle dung pollution of water in the areas they settle. Insecurity as a result of crop farmers and herders' conflict in Nigeria is a trending issue coupled with a lot of negative impacts on the citizenry. The root causes of the ongoing crisis include poverty, the quest for grazing resources, inefficient negotiation mechanisms, poor governance, corruption, and cattle rustling among others (Okoli and Okpaleke, 2014). These clashes have remained unsolved as farmers and communities have continued to deploy local militias and expanded household investments in guns and lethal weapons. Consequently, food insecurity as well as human insecurity has become a common challenge in many states as a result of herdsman attacks and farmers-herdsman conflicts (Achumbo *et al.*, 2013). The farmers-herder clashes sometimes are a result of historical,

climatic, post-colonial influence, oil dependency, and ethnicity and religious dimensions (Achumbo *et al.*, 2013). The violent battle between herders and farmers is currently taking place throughout more than half of the Middle Belt region in central Nigeria, which includes Adamawa, Kwara, Bauchi, Kogi, Nasarawa, Niger, Plateau, and Taraba as well as the Federal Capital Territory (Abuja). There have been fatalities and property losses as a result of this war spreading to other regions of the country. Additionally, it has resulted in the internal displacement of thousands of individuals, who have multiplied into refugee camps across the country. In North Central, over 70% of farmers were displaced from their homes while hundreds of people were reported to have been killed during attacks in the Taraba and Adamawa states of Northeastern Nigeria (Lenshie, 2020). While Nigerian society and economy still heavily rely on dairy and agriculture for food security, the difficulty of insecurity makes it tough to achieve sustainable food production, casting a gloomy future for the nation. Conflicts do not only destroy agricultural production, but they also result in poor commercial performance, unneeded firm closures, a drop-in employee numbers, unemployment, and a high level of poverty among entrepreneurs in the affected zones.

Dairy resource sustainability

To achieve a sustainable dairy sector in Nigeria, there is a need for a strategic partnership and collaboration between all stakeholders which directly secures value for every player (the government, research institutes, and private sectors) in the chain, a triangular partnership model must be adopted (Figure 2), through which the government make policies that will encourage the investors to establish dairy production and collection centers and the farmers actively cooperating with these private sectors. Research and development through the breeding of animals with high reproductive capacity can be performed with the support of government and external funding. The local breeds can also be improved by crossing with breeds that are heat and disease-tolerant (Hoffmann, 2008).

Extension agencies also play a key role in the dairy sector. Collaboration between research institutions, governments and farmers should also be strengthened. There is a need for foreign investors to invest in private milk collection companies by providing resident full-time specialized extension agents at the collection centers to provide the dairy farmers with all the support needed. Import tariffs should be set up to help and gradually increase as domestic production rises, and research and development of domesticized technology and practices are some of the remedies proffered to reach domestic viability. Value-added incentives can also be introduced. Insemination to improve high-yield hybrid cattle, improved feed and fodder systems, water access, extension services, and milk technology should be prioritized.

Removing charges on dairy equipment and cold chain infrastructure for aggregation, collection and evacuation is an incentive for the value chain. This should be rewarded for its performance. Concessional loans should be used to improve local production. Farmers can be provided with asset-based credit, which negates the risk of financial institutions. It can be done by providing loans for the purchase of dairy cows which are insured, and their value is used as a security.

In other to ensure sustainable dairy development and

food security in Nigeria, all hands must be on deck in arresting the protracted farmer conflicts as there would be a stalled development of any nation devoid of peace, tranquility and justice. The federal government should revisit the ranching zone policy originally initiated to provide more grazing areas. They should also regulate the availability of guns and other lethal weapons, especially among local and unauthorized personnel. Reforestation and irrigation farming should also be encouraged in the desert-prone states to forestall the continued movement of herdsmen into Southern Nigeria which consists mostly of Christian crop farmers. Apart from bringing a lasting solution to the farmers-conflict, integrating modified grasses into the ranching systems can significantly improve milk yield production, and reduce zoonosis, and threats posed by the nomadic lifestyle

of the herdsmen. This will encourage people to support the government's ranching strategy, either as private landowners where these grasses can be produced or by utilizing ranches that the government provides.

Meeting the future need of the growing population requires promoting more sustainable development models for the dairy sector with the involvement of every stakeholder especially the government to ensure the sustainability of the natural and human systems, also the social, environmental, and economic factors must be considered which will result in efficient and increasing use of resources, protecting and improving rural livelihoods and social well-being, increasing the resilience of the dwellers, communities, and ecosystems, while addressing climate change and market volatility.



Figure 2: Triangular partnership among stakeholders in Nigeria's dairy sector

In Nigeria's dairy sector, however, the dairy value chain sector has experienced little or no support from extension services due to factors like lack of dairy value chain specialized extension services, lack of intensive university courses on the dairy sector, weak linkages between research institutions, extension agents and the farmers, lack of structured information dissemination process. Equipping the extension agents with relevant skills and equipment needed in the dairy value chain, and providing selected farmers, agriculture students, and extension agents with specialized training sessions and short study programs would impact positively dairy resource sustainability.

Application of new technologies to improve dairy

sustainability

Nigeria is rated the most populated country in Africa (Worldometer, 2023). To ensure that the ever-increasing population is food secure, there is a need to double the current food production effort and practices. Although dairy farming significantly contributes to national food security, livestock management, and milk processing activities including fertilizer, concentrate, water and energy use, livestock feed, farming system, milk processing method, packaging, transport, refrigeration, and dairy waste are significantly impacting the environment and natural resources. With a global average milk yield of about 2600 kg/cow/year, there are currently more than 270 million dairy (or dual-purpose) cows in the world with only 33 nations producing more than 6,000 kg of milk per cow per year (Figure 3). The Global Livestock Environmental Assessment Model (GLEAM) estimates that cattle rearing and grazing release about 4623 million tonnes of carbon to the environment and dairy production constitutes about 46% (FAO, 2018). This development causes global warming and affects the environment and food production negatively.

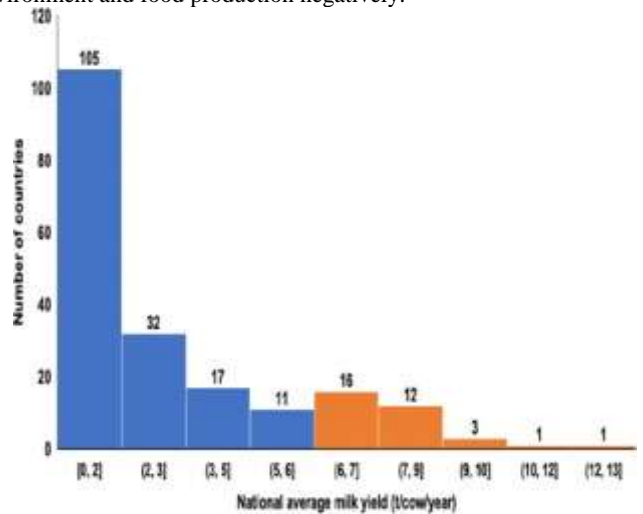


Figure 3: Distribution of countries according to their national average dairy cattle milk yield (t/cow/year) (FAO, 2020)

Innovative technologies are the primary requirement and determining element for the sustainable development of dairy farming according to scientific studies and top agricultural enterprises. The utilization of digital technology, active implementation, and the application of clever automated process control systems are priorities for sustained dairy development in the modern world. Modern-day dairy farmers and processors continuously improve cow comfort, milk quality, productivity, and sustainability through smart farming technologies, novel feed additives and methane digesters, robots, and water and energy conservation technologies. Carbon-neutral and plant-based milk products have also become common in the dairy market leading to safer and more wholesome dairy products (Adesulu-Dahunsi *et al.*, 2023).

The use of smart dairy farming methods, the Internet of Things (IoT), different AI techniques and other digital technologies including energy inputs (by using Renewable Energy Sources) in cattle and animal

management can assist a farmer to overcome different traditional farming challenges and increase milk production (Cogato *et al.*, 2021). It ensures the high productivity of quality milk and determines the level of modern dairy sustainability (Lyashenko *et al.*, 2022). Today's dairy business is not only digitalized but has also adopted modern farming technologies which aid farm managers in effectively completing their tasks and ensuring food security. The competition for market share and rising demand for milk and dairy products accelerate the development of digital technologies in the dairy sector and open doors to sustainable growth, boosting agribusiness efficiency (Lyashenko *et al.*, 2022). By utilizing cutting-edge sensing and data analysis technology, smart dairy farming is a widely accepted idea that can meet the rising demand for high-quality dairy products, lessen environmental problems, use fewer resources, and improve animal health.

Modern dairy farmers have learned how to alter genetics to produce more milk from fewer cows by concentrating on sustainable agricultural techniques. As a result, fewer greenhouse gas emissions are generated. Cows that are more productive than their forebears are selected and bred through innovative technologies such as artificial insemination, genetic breeding and phenotyping technologies. This enables dairy farmers to breed cows with superior genes for milk production in a secure environment without losing genetic diversity or destroying key biological mechanisms (such as health, resilience, robustness, welfare, and longevity) in the most common dairy cattle breeds. The adoption of digital technology on dairy farms shows a considerable demand for a high degree of expertise for dairy personnel (Barragan *et al.*, 2016).

Depletion of freshwater supplies caused by population growth, natural disasters; drought, fire, flood, and rising global food demand makes sustainable water management one of the greatest challenges. Water is an important resource for agriculture, and dairy farming represents over 20% of total agricultural water use in areas with intensive dairy farming. Without access to clean water, a dairy farm will not be operational. Water is used for crop irrigation, directly consumed by cattle, and for cleaning milking equipment, facility safety, milk treatment, milk quality, and manure handling. Today, many dairy farmers across the globe use subsurface drip irrigation to grow feed crops and utilize other innovative technologies to conserve water and ensure dairy sustainability. To process dairy products, processors utilize a variety of technological tools, such as pressure change technology for pasteurization, extruder technology for texturization, microwave technology for pre-heating concentrates, and closed loop and superheated steam technology for spray drying of skim milk powder. The use of microwave technology to pre-heat curdled soured milk before spray drying has been reported to result in significant water and energy savings (Michels *et al.*, 2019).

Combining appropriate technological models in many cases is the key to achieving the desired changes and improving dairy resource sustainability. In terms of milking technologies, Cogato *et al.* (2021) reported that the robotic milking system is more water efficient than other milking parlours, as automatic milking and washing systems use a precise amount of water per time. Similarly, water consumption by cattle cannot be assessed. However, applying a combination of water conservation strategies such as air temperature reduction,

complete recycling of milk-cooling water, and modified cow preparation protocol could significantly reduce the total annual water use in dairy farms. Production processes, energy use, and dairy waste are recognized to be the main causes of environmental footprint (FAO, 2018). It has been reported that packaging materials, particularly for infant formula, and energy usage, across selected life cycle stages, should be targeted as these are the most significant contributors to the overall environmental impact. Thus, green engineering and novel packaging materials should be explored to ensure sustainable dairy development and reduced impact on the environment.

Impact of Government policies on dairy production in Nigeria

Policies determine the managerial rules that ultimately contribute to the success of the production of food and dairy products to meet the escalating increase in food demand in Nigeria. The need to have a consistent production of livestock animals to achieve food security is essential to the economy of any nation, and it is important to note that policy issues are critical in the production of livestock animals. Adopting the right policies for livestock animals will greatly contribute to the national and economic development of any country. In Nigeria, the Department of Animal Production and Husbandry Services (DAPHS), situated at the Ministry of Environment, is saddled with the responsibility of growing the country's animal resources through monitoring and improvement of grazing reserves. The duties assigned to this agency are quite far from being accomplished due to so many challenges.

The Food and Agricultural Organization of the United Nations, in its report on the future of livestock in Nigeria, identified the need to take into consideration the growing population of people in Nigeria and the demands for a better living. Animal migration from rural to urban areas is increasing as animal and human populations grow. This has devastating consequences for humans and animals. Some of the consequences identified are transmittable zoonotic diseases and the indiscriminate administration of antimicrobials to farm animals, environmental degradation which compounds the problem of food crises and security issues in rural settings (FAO, 2018). This report encapsulates the urgent need to develop livestock policies that will aid in the control of zoonotic diseases and prioritize public health, thereby ensuring the long-term development of livestock.

It had been reported that Nigeria produces millions of animals a year, and these animals are usually raised by herders using the free-range system (Olajide and Akpan, 2020). Currently in Nigeria, the most challenging system of farming is the free-range system. This system of rearing cattle for meat and dairy products has generated incessant conflicts between pastoralists and farmers, which have constantly led to the loss of lives and properties when conflicts arise (Ogboru and Adejonwo-Osho, 2018). There are constant struggles by concerned parties for grazing grass and the protection of farmlands. In Nigeria, there is no federal law regulating systems of rearing cattle; therefore, pastoralists adopt systems that are most suitable for them. The impacts of unregulated cattle grazing are enormous and have devastating consequences that need urgent legal attention. Some of these challenges range from loss of life and insecurity through herder-farmer conflicts to loss of cattle through

deliberate killings, environmental impacts, etc. The ECOWAS Regulation on the implementation of the transhumance protocol identified the free-range system of farming as a contributing factor to social, environmental, health, economic, and political decadence, despite the enormous benefits that livestock production brings to the development of a nation. It recommended the adoption of intensive forms of animal husbandry that are devoid of the current challenges associated with free-range cattle herding be adopted.

An examination of the legal framework in place for cattle rearing reveals that these laws are outdated and cannot withstand the current challenges faced by concerned parties (herders and farmers). The Grazing Reserve Law, of 1965, was the very first piece of legislation enacted by the Northern regions regulating the movement of cows from place to place. It is worth noting at this point that cattle herding originated in Northern Nigeria; however, as the prevalence of trypanosomiasis decreased, cattle herding gradually spread to the country's southern regions. Section 3 of the Grazing Reserve Law, 1965, empowered the governments of various northern regions to constitute lands (government or native lands) as grazing reserves where the Minister believes that such government or native land should be protected and reserved for grazing. With the abolishment of the use of regions in the northern parts of Nigeria, northern states gradually subsumed this law (the Grazing Reserve Law, 1965) into their state laws. On the ground, cow herding has spread beyond the northern states to the southern states, where there are no laws governing public cow herding.

The National Environmental Watershed Mountains, Hilly, and Catchment Areas Regulation, 2009, is another piece of legislation regulating the herding of cattle in protected mountains, hilly areas, and other catchment areas. This piece of legislation appears to regulate the herding of cattle in selected areas, but in reality, no piece of land has been reserved for any of the purposes for which the law was enacted. Regulation 5(4)(a) provides that the local governments, in conjunction with the state government, could conserve resources in an area threatened by degradation. Uncontrolled cattle herding could deplete our natural resources, such as soil degradation. Regulations 9 (1) and (2) expressly provide that the Agency, in collaboration with state governments, shall limit grazing to areas that are protected watersheds, mountains, hilly areas, and catchment areas that have been identified as threatened with environmental degradation.

As a result of the constant conflicts between herders and farmers, some state governments in the Southern states have enacted anti-grazing laws to reduce the menace caused by free-range cattle rearing. Some of these states include Oyo, Bayelsa, Ekiti, Abia, Ebonyi, Taraba, Benue, etc. Despite the enactment of these laws, implementation has been a mirage due to protests from pastoralists. Some of the issues raised by herders are based on religion, paucity of funds to establish ranches, unavailability of land for herding animals in secluded areas, and unavailability of lands as grazing reserves. Pastoralists have also identified other challenges such as the exponential growth of the human population, the lack of sufficient grazing reserves, political marginalization, insufficient institutional support to establish the desired ranches, rural banditry, and cattle hustling.

Conclusion

The Federal Government of Nigeria emphasizes the role of agriculture as an engine of growth and poverty reduction. The development of various value chains is what can be used to achieve these. In many developing countries, dairy production is strongly influenced by the development of agricultural land and food security, as it creates jobs for many, especially for the female folks. Reducing reliance on imports, creating more jobs and income, research and development on the improvement of the local breeds of animals that can withstand the environmental conditions and improving productivity in the livestock and dairy value chain will go a long way in achieving more.

Issues affecting livestock production should be taken seriously to enhance the sustainable development of a country through the provision of adequate food to meet the demands of the growing population. To achieve this, it is expected that the federal and state governments will enact livestock policies that will drive the desired agenda. There should be a holistic approach that takes into consideration the peculiarities of pastoralists and farmers. This approach has the possibility of impacting and promoting sustainable dairy development in Nigeria and ensuring food security. If all the factors highlighted are adequately addressed, through mass literacy programs, government interventions in providing the basic social amenities, policies, sensitization and proper training of the dairy farmers by the extension workers, maintenance of hygienic practices during milking to curb any foodborne/food related diseases, and the potentials of the economic gain from dairy farming among others, there will be a great improvement in the dairy industry and could put an end to food insecurity in Nigeria.

To stimulate sustainable and economically viable dairy production and management in Nigeria, stakeholders must be prepared to spend money on training experts in well-developed countries

i.e. The Netherlands who are vast in the use of artificial insemination services. The dairy sector needs strong and well-equipped research laboratories to stay current on the trending issues in the dairy industry. Finally, it is recommended that the federal government and other important players in the dairy sector including dairy collection and processing industries should support and replicate some of the innovative and laudable dairy development strategies currently rolled out by the Friesland Campina WAMCO.

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The authors declare that there are no known conflicts of interest.

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