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16th INAUGURAL LECTURE

TOPIC:

THE ROMANCE OF AN ACADEMIC WITH ENZYMES THAT ALL MAY BE FED

by

Professor T. E. LAWAL
Professor of Animal Science

RED HALL
COLLEGE OF HEALTH SCIENCES,
BOWEN UNIVERSITY, IWO

Date:
Thursday, 24 October, 2024
Time: 2:00pm

BOWEN UNIVERSITY, IWO
INAUGURAL LECTURE

Professor T. E. LAWAL
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Protocol
The Vice Chancellor
The Deputy Vice Chancellor
The Registrar
The Bursar
The University Librarian
The University Chaplain
The Provost, College of Agriculture, Engineering and Science
Provosts of other Colleges
Directors and Heads of Programmes / Units
Professors and other Members of Senate
Other Academic and Professional Colleagues
Members of Administrative and Technical Staff Members of my Immediate and Extended Family,
Friends of the University and other Invited Guests
My Lords Spiritual and Temporal
Gentlemen of the Press
Distinguished Ladies and Gentlemen

1.0 INTRODUCTION

I am loaded today with heartfelt gratitude to the almighty God for the privilege to be alive and to witness this epochal and momentous occasion in my teaching and research career. I do not trivialize this opportunity and great honour. I am very grateful to Mr Vice Chancellor (Professor Jonathan O. Babalola), who is the Chairman of this occasion. I thank you Sir and I pray that you will fulfill the purpose of coming to Bowen University in Jesus name, amen.

Distinguished audience, an inaugural lecture provides the opportunity for a professor to reveal to the public his or her specialization / expertise and present his or her contributions to scholarship. Mr. Vice-Chancellor, in Animal Science, we believe that animals and human beings, are products of two things: the environment and the genetic make-up. I was born in Ayetoro, an agrarian community in Yewa North Local Government Area of Ogun State. Waking up and going to farm was a normal lifestyle to us. In addition, feeding grains to chickens was a daily or normal routine to me as a growing lad. With this, studying agriculture for me is akin to asking an indigene of Ijebu, Ijesha or Ijebu-Jesha to study Economics or Accounting. Thus, my practice of agriculture dates back to the innocent days of childhood. I consider it a big privilege to address this gathering on the management and conversion of wastes into feed through the instrumentality of enzymes for our animals with the ultimate aim of increasing food productivity and availability, most especially animal protein. Low feed production cost can be achieved if the use of unconventional Agro-Industrial By-products (AIBs) is put into consideration. The ever widening competition between humans and livestock is the primary cause of unabated increase in the cost of conventional feed ingredients. This increase, undoubtedly, affects the cost of feeding, which may be unaffordable for many farmers. Researchers are therefore challenged to find alternatives to these conventional ingredients like maize, groundnut cake, soya bean meal and meat meal. So far, the considered alternatives are the Agro-Industrial By-products. AIBs are obtained from agricultural products after the main products have been obtained. They are the most abundant renewable resources on earth and they are considered because they are available and inexpensive. Furthermore, it is pertinent to consider the use of AIBs because they now constitute environmental nuisance in some cases. Hence, recently there has been a great campaign for the exploitation of these wastes as low cost materials for the production of microbial enzymes through the instrumentality of solid state fermentation or submerged fermentation techniques.

1.1 THE PROFESSION INSTITUTED AND BLESSED BY GOD

According to the Bible, at the creation of the world, God in **Gen. 1: 24 (KJV),** said “Let the earth bring forth the living creatures according to its kind; **and cattle** after their kind and the beast of the earth according to its kind and it was so”. In addition, God also said “let the earth produce **all kinds of animals,** life domestic and wild large and small and it was done” **(Gen. 1: 25 KJV)**. In addition, Noah was a good domesticator (**Gen. 8: 1; Gen. 9: 10 KJV)** and God made a covenant with him that neither shall **the fowl, the cattle, sheep and goats, and of, every beast of the earth be cut off any more by waters of flood** (**Gen. 9: 8 – 11 KJV**) (Emphasis Added).

Mr. Vice-Chancellor, Sir, I make bold to say that the first profession ordained by God is farming **(Gen.2: 5 – 10 KJV)** and from the scriptures quoted above, livestock production is a conspicuous part of it. Livestock production is as old as the Bible days. For instance, in Genesis 13: 1-18, the Bible says '…**AND ABRAM WAS RICH IN CATTLE**, in silver and in Gold." Besides, in **Genesis 46: 33 – 34 (KJV),** Joseph told his brothers "when the king (Pharaoh) calls for you and ask what your occupation is, be sure to **tell him that you have been taking care of livestock all your life**". (Emphasis Added) Mr. Vice Chancellor Sir, this lecture will thus give me the privilege to tell this distinguished audience and the world at large that the occupation ordained and blessed by God has been and will always be livestock agriculture. This profession has birthed great men and women. Some of the richest men in the Bible were Abraham, the father of nations **(Gen 13: 2 KJV),** his son Isaac and grandson Jacob. They were confirmed Animal Scientists and they had large populations of livestock. In addition, Job, a descendant of Abraham possessed 7000 sheep, 3000 camels, 500 yokes of oxen and 500 female donkeys **(Job 1: 3 KJV)**.

2.0 ANIMAL PRODUCTION IN NIGERIA

(a) Contributions of Livestock to Nigeria Economy

The population of Nigerians is estimated to be above 200 million and we rear 146.1 million ruminant livestock which include: Cattle -21.2 million, Sheep - 48.6 million and goats - 76.3 million). In addition, there is an estimated 166,564,000 million chickens (FAOSTAT, 2021). The livestock sector, which includes cross-border trade of live animals and animal products, contributes between 5% and 30% to the National Gross Domestic Product (GDP) in African dry land countries; in West Africa. For instance, it constitutes 40% of agricultural GDP (Molina-Flores *et al.,* 2020). In Nigeria, cattle are very important in the socio-economic outlook of the citizens because they contribute about 35 % of animal meat supply, income (foreign exchange), employments, etc. (Oshim and Nze, 2024). Animal protein intake in Nigeria, through statistics, is estimated at 18 g/head/day and this is far below the prerequisite of 35 g/head/day recommended by the Food and Agricultural Organization of the United

Nations (Lucas, 2022). This explains why we see some children and adults in Africa that are runts and dwarfs. This is very uncommon in Europe and United States of America, except those who are genetically deficient, because they do not eat well. They have access to required protein which will aid brain and body development as expected. If the parents cannot afford infant food, they have government agencies that will take care of that.

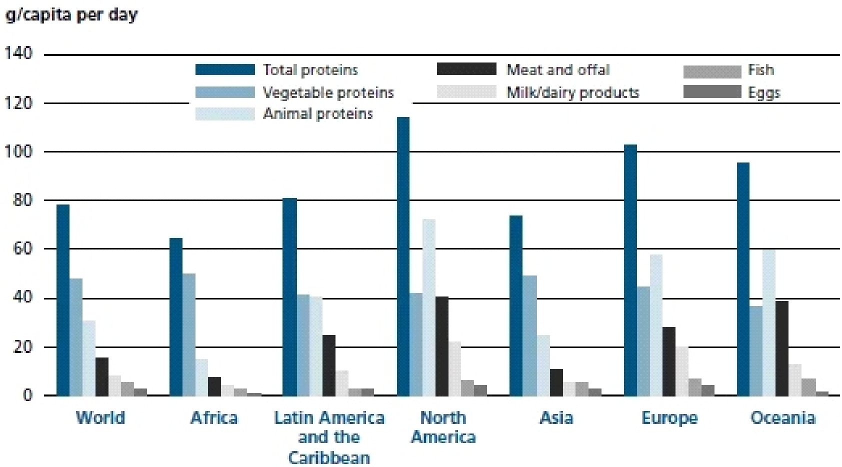

Figure 1: Total Protein Supply by Continents and Major Food Group (FAO 2023)

Table 1: Selected Livestock Population in Nigeria

Species	Year	Number
Cattle	2021	21,162,929
Sheep	2021	48,637,013
Goats	2021	76,292,153
Camels	2021	293,915
Horses	2021	107,357
Asses	2021	1,369,121
Swine/Pigs	2021	8,092,066
Rabbits	2021	4,939,000
Chickens	2021	166,564,000
	TOTAL	329,457,554

Source: FAOSTAT (2021) adapted by Fajemisin (2023)

2.1 INHIBITIONS TO LIVESTOCK PRODUCTION IN THE TROPICS

1. Environmental Challenges

The tropical climate is characterized by high temperatures and humidity, which can lead to heat stress in animals, reducing feed intake, growth rates, reproduction efficiency, and overall productivity (Matheus *et al*., 2024). Dry and wet seasons affect feed availability and quality, with scarcity during the dry season leading to poor nutrition and water shortages. Tropical pastures are often of low nutritional value, with high fiber content and low digestibility, impacting livestock's growth and milk production. The prevailing temperatures, relative humidity and levels of solar radiation are generally above the comfort range for optimum efficiency of livestock production. Animals are forced to adapt, by the expenditure of extra energy to maintain thermal balance. Milk production, by dairy cows is very sensitive to high environmental temperatures.

2. Nutritional Challenge

Limited availability of high-quality forage, lack of protein-rich supplements, and mineral deficiencies reduce livestock performance (Carrasco and Carrasco, 2024). During dry seasons, pastures dry up, and stored feeds are often inadequate, leading to weight loss and reduced productivity. Insufficient access to clean water affects animal health, feed intake, and overall growth. In any region of the world, a major problem associated with the development of the livestock industry is the supply of livestock feed. In poultry and pig production, over 70% of production cost is estimated to be due to the cost of feed. A major constraint in cattle production is the lack of grazing reserves.

3. Disease and Parasite Burden

The tropics are home to numerous livestock diseases such as Foot-and-Mouth Disease (FMD), African Swine Fever (ASF), Newcastle Disease, and Peste des Petits Ruminants (PPR). High prevalence of internal and external parasites (ticks, helminths) reduces animal's health, productivity, and can lead to death if untreated. Africa was described as the paradise to the parasites (Struthers 2024). Inadequate access to veterinary services, vaccines, and medications exacerbates the impact of diseases and parasites.

4. Inadequate Marketing Organizations

This includes processing and storage facilities for the excess fruits, grasses, and grains when they are produced. Besides, there is poor market availability. I mean there is no located place or places designated by government for farmers to take their products to in case they do not have a market. In addition, processing is a big problem to farmers in Nigeria as there is very poor availability of processing centres and electricity (Akuru *et al.,* 2017).

5. Genetic and Breed Limitations

Many indigenous breeds have low productivity (e.g., milk yield, growth rate) compared to improved breeds but are often kept due to their adaptability to harsh environments (Endris and Feki, 2021). A typical White Fulani or Bokolo breed of cattle will give three to four litres of milk per day whereas a Girolando or Holstein Friesian breed will give about fifty litres of milk per day! This was my experience in India where one gaolao breed will sustain a family and also provides financial reward to the family. Farmers often lack access to genetically superior breeds that are more productive and disease-resistant. In this aspect, the Friesland Campina WAMCO should be applauded as they often make available semen of exotic breeds for the improvement of ours.

6. Socio-Economic Factors

Poor Infrastructure

Inadequate and poor roads infrastructure, markets, and storage facilities limit access to inputs and markets, increasing production costs and reducing profitability. An average herd of cattle may trail at a distance of 400-600km.There may be little gain from their sale because of weight shrinkage. Insufficient capital for implementing innovations in animal production. Many farmers lack access to credit and insurance facilities, limiting their ability to invest in better livestock management practices, feeds, and veterinary care. It is rather unfortunate that government's loans to farmers do not get to farmers but get to those that are not real farmers. In our society, man-know-man is one of our challenges. Lack of knowledge and training on improved livestock; poor educational background of the intended users (farmers) on technology and inadequate means of informing farmers of worthwhile changes and the land tenure system, are some other challenges. The dominance of the nomadic herdsmen in the livestock industry using traditional production techniques due to lack of education is also an issue. Thanks to the government for the introduction of nomadic education even though it is not a total success but it is something plausible. Ineffective policies and lack of support from governments often result in inadequate extension services, poor disease control measures, and limited support for research and development. Uncertain land ownership and limited access to grazing land can restrict livestock production and lead to overgrazing and land degradation. The general rule is that farmers must have an acre of land for a cow! This is one of the reasons behind communal clashes between farmers and herders. Averagely, a cow eats 2.5 to 3% of its body weight a day. So, if a cow weighs 400kg, it will consume about 12kg per day (Ugwueze *et al*., 2022).

Increase in Population

The projected global population statistics for 2024 indicates a significant increase, with estimates suggesting a total population of approximately 8.05 billion. This projection is based on various methodologies, including Bayesian probabilistic models and traditional cohort-component methods, which account for factors such as fertility, mortality, and migration trends. In the year 2000, our population in Nigeria was estimated to be 123 million, but today the population is over 200 million. As at 18th October, 2023, the population of Nigeria has risen to 227,882.945 but as at September, 2024, our population was 232, 679,478 (Worldometer, 2024).

#	Region	Population (2024)	Yearly Change	Net Change	Density (P/Km^2)	Land Area (Km^2)	Migrants (net)	Fert. Rate	Med. Age	Urban Pop %	World Share
1	**Asia**	**4,806,898,007**	0.6 %	28,893,521	155	31,033,131	-2,335,416	1.9	32	52.9 %	58.9 %
2	**Africa**	**1,515,140,849**	2.32 %	34,370,324	51	29,648,481	-644,272	4	19	44.5 %	18.6 %
3	Europe	**745,083,824**	-0.07 %	-519,051	34	22,134,900	1,566,027	1.4	43	75.6 %	9.1 %
4	Latin America and the Caribbean	**663,466,072**	0.69 %	4,574,555	33	20,139,378	-382,944	1.8	31	85.2 %	8.1 %
5	Northern America	**385,295,105**	0.62 %	2,392,363	21	18,651,660	1,654,440	1.6	39	82.2 %	4.7 %
6	Oceania	**46,088,716**	1.15 %	525,929	5	8,486,460	142,167	2.1	33	66.1 %	0.6 %

Table 2: World population by regions
Source: Worldometer (2024). https://www.worldometers.info/world-population/#region

The United Nations has opined that Nigeria's population would be 364 million in 2030, and 480 million by 2050. The question begging for answer, Mr. Vice Chancellor, Sir, how do we feed this gargantuan population?

The increase in the population as noted earlier has put a lot of pressure on land and water resources used by the key actors in the farmers-herdsmen conflict. This increase demographically has led to an expansion in agricultural fields and a reduction in grazing areas for herdsmen (Fajemisin, 2023). This reduction in resources has increasingly led to competitions that are not healthy. The southward movement of herdsmen has resulted in conflicts in the Middle Belt region of Nigeria particularly, in Plateau, Kaduna, Niger, Nasarawa, Benue, Taraba and Adamawa States. These conflicts have led to the demise of many Nigerians especially the farmers, and the displacement of so many villagers whose villages have been attacked by herdsmen (Akpoghome and Adikaibe, 2018). Bowen University, under the leadership of Prof. Jonathan Oyebamiji Babalola, is not insensitive to peace and conflicts resolution management. The Senate of the University therefore set up a committee to look into perpetuation of peace in our environment and Nigeria at large. I am pleased to be a member of that committee under the chairmanship of Prof. Lere Amusan.

Table 3: Population of Nigeria (2024 and historical)

Year	Population	Yearly % Change
2024	**232,679,478**	2.10 %
2023	227,882,945	2.12 %
2022	223,150,896	2.11 %
2020	213,996,181	2.15 %

Source: Worldometer (2024). https://www.worldometers.info/world-population/#re

FROM THE GUARDIAN, AUGUST 14, 2024

Comptroller-General of Customs, Adewale Adeniyi on the 14th of August, 2024 said "Suspension **of tariffs on food** imports **to cost Nigeria N188b".** He revealed a dramatic increase in the country's food imports, which soared by 95.28 percent to N920.54 billion in the first quarter of 2024 from January to March from N471.39 billion recorded in the same period of the previous year. Comptroller-General of Customs, Wale Adeniyi, disclosed this in Abuja, during a press briefing, emphasizing that the tariff removal policy will lead to significant revenue forfeiture, estimated at approximately N188.37 billion over six months. He further said: "Nigeria boasts of 84 million hectares of arable land, of which only 40per cent is currently cultivated according to the PricewaterhouseCoopers (PwC) report of 2017 on 'Boosting Agricultural Productivity in Nigeria.' This presents an enormous opportunity for agricultural expansion. With a population of over 200million, Nigeria represents a vast market for food products, both locally produced and imported." Mr. Vice Chancellor, Sir, Reverend Israel Oludotun Ransome- Kuti, the father of Professor Olikoye Ransome-Kuti, Dr. Bekolari Ransome-Kuti and Olufela Anikulapo Kuti and the husband of Olufunmilayo Ransome-Kuti was the principal of Abeokuta Grammar School and he kept telling his students that *"mens sana in corpore sano"* meaning that a sound mind can only be found in a sound body. Nigerians must be able to feed themselves because according to Winston Churchill, the Prime Minister of United Kingdom between 1940 and 1945 'a nation that cannot feed itself is not free'.

2.2 PRODUCTION OF LIVESTOCK AND LIVESTOCK COMMODITIES

Meat has been a fundamental part of the human diet for millions of years, occupying a prominent place in many global culinary traditions, with annual consumption and production worldwide reaching up to 350 metric million tons. In addition to its cultural importance, meat serves as a vital source of essential amino acids, vitamins, and minerals such as iron, zinc, and selenium. These nutrients are essential for growth, development, and overall health. In Nigeria, meat is an integral part of most meals, and its significance extends beyond its role as a source of nutrients: it plays a central role in the social fabric of the country, fostering a sense of unity and tradition among the people. In Nigeria, a wide spectrum of meat sources play a crucial role in influencing the nation's preferences for animal protein, with beef reigning as the predominant choice. Complementing this preference are options such as chicken, chevon (goat meat), mutton, pork, venison, and an array of other animal meats. The prevalence of beef can be attributed tothe substantial cattle population in Nigeria, surpassing that of other animal species. China is the world's largest meat producer, producing 253,024,735 tonnes in 2023. This accounts for 25.91 percent of global meat production. The remaining top five countries are the United States, Brazil, India, and Russia, all of which account for 54.65% of global meat output. The top 20 meat producers account for more than 75% of global meat production. Other countries that produce meat include Italy, the United Kingdom, Pakistan, Canada, and Spain (Batista, 2023). In 2023, China produced more than 54 million metric tons of pork, about 20 million tons of chicken, and approximately 6 million tons of beef. The top five countries producing beef and buffalo meat are China, Brazil, India, Argentina, and the United States. South Africa is the largest producer of beef and poultry in Africa, with 1,038.7 million and 1.9 million metric tonnes of production, respectively. South Africa's population has now exceeded just 63 million in human population, according to the latest mid-year population estimates for 2024. The country's population grew by approximately 835,513 individuals, marking a 1. 33% increase from July 2023 to July 2024. The above contradicts our case in Nigeria. Our human population is 232, 679, 478 as at July, 2024 and our meat production is 326.4 metric tons. This shows the reason an average South African eats better than an average Nigerian (United States Department of Agriculture Foreign, 2024). Ethiopia, which had the largest cattle stock on the continent, registered an output of 433,000 metric tons of beef and veal. Ethiopia and Tanzania are two of Eastern Africa's leading livestock producers. Ethiopia boasts of the continent's largest livestock population, while Tanzania also has substantial numbers. Despite their large herds, productivity and commercialisation in both countries remain low. For instance, meat exports from Ethiopia and Tanzania constitute only a small fraction of their overall export commodities (The East Africa News, 2024;

Kibona *et al*., 2022). Global milk production in 2023 reached 950 million tonnes, an increase of 1.3 percent year-on-year, a faster pace compared to the 0.6 percent growth registered in 2022, principally driven by volume growth in Asia, specifically in India and China, with moderate growth in the rest of the world and potentially lower production in Africa. In Asia, milk output is expected to reach 431 million tonnes, up to 2.3 percent from 2022, underpinned by output expansions in some leading producers, notably India, China, Pakistan, Türkiye, Uzbekistan and Kazakhstan. However, significant production drops are anticipated in Japan, the Republic of Korea and Iraq, offsetting increases elsewhere. In North America, milk output is pegged at around 113 million tonnes, increasing by 0.3 percent from 2022. In the United States of America, despite lower milk prices and high feed costs that induced farmers to reduce cow herd number, especially in the second half of the year, increases in milk yields could sustain a production growth of around 0.3 percent, with output reaching 103 million tonnes (FAO, 2024). Similarly, higher milk yields and increased farmgate prices could incentivize farmers to produce more milk in Canada, lifting output by 0.6 percent to 9.8 million tonnes. In Central America and the Caribbean, milk production is forecast to increase by 1.3 percent in 2023 to 20 million tonnes, principally driven by Mexico, which accounts for 70 percent of the regional milk production, where favourable weather and improved production facilities could lift milk production by 1.8 percent to 14 million tonnes. However, contrary to developments in milk production in other regions as observed in the above statistics, in Africa, milk production was at 53 million tonnes in 2023. There was downward trend of 0.6 percent from 2022. This reflected output drops in Kenya, Egypt and Ethiopia, among others, due to droughts in leading milk-producing regions, smaller herd sizes, below normal fodder availabilities, poor genetic improvements and ongoing conflicts (Dairy Market Review, 2023).

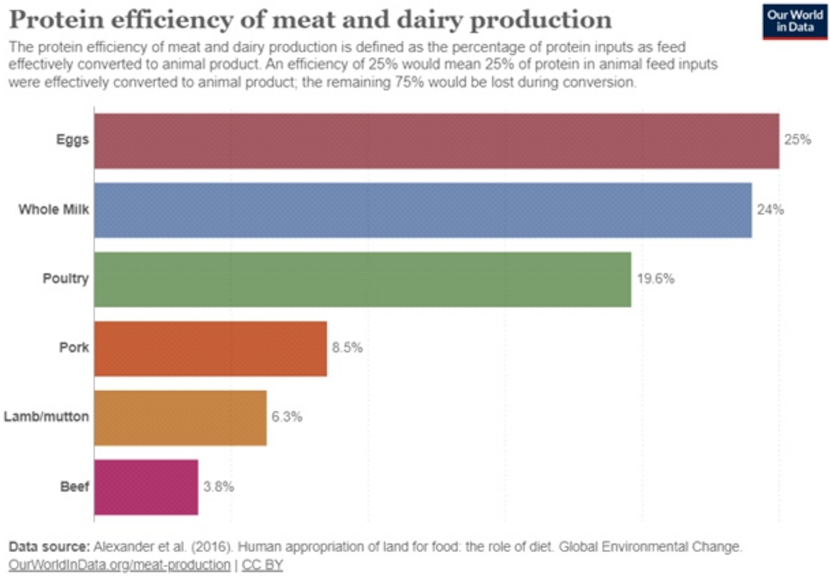

Figure 2: Protein efficiency of meat and dairy production

2.3 What Is Hunger?

When people talk about 'hunger,' they often refer to the feeling of 'being hungry.' However, when experts and aid organizations like the WHO talk about hunger, what they mean is **a prolonged period in which people experience extreme food insecurity.**

Vulnerable populations can go for days without eating due to a lack of money, access to food, or other resources. In this sense, hunger is in part defined by the **distress associated with the lack of proper nutrition** or access to food.

Hunger is a multifaceted problem that can be discussed both at an individual level and as it applies to larger populations. In 2022, Asia was home to 55 percent (402 million) of the people in the world affected by hunger, while more than 38 percent (282 million) lived in Africa (World Health Organization (2023).

3.0 MALNUTRITION

Having introduced this lecture with a discussion on the production of animal protein, I will like to address the issue of malnutrition and the deprivation of animal protein. Protein is important for growth, maintenance and protection of the body. Both adequacy of protein quantity and protein quality in diet are important to guarantee obtaining all the essential amino acids. Protein–energy malnutrition is widely present in developing countries such as Nigeria and might result in stunting and wasting. Needs for protein differ depending on age and physiological status and are higher during growth, pregnancy and lactation (Haradhan, 2022).

Malnutrition in Africa is a significant public health challenge, contributing to high rates of morbidity, mortality, and impaired development, particularly among children and vulnerable populations. The problem of malnutrition in Africa is multifaceted, influenced by various factors, including food insecurity, poverty, inadequate healthcare, and poor dietary practices. (Adeyeye *et al*., 2017). Here's an in-depth look at the causes, types, impacts, and potential solutions to malnutrition in Africa.

3.1 Causes of Malnutrition in Africa

There is poor access to nutritious food and many families cannot access or afford a variety of nutritious foods and this has led to diets high in carbohydrates but low in essential nutrients. Experience of droughts, floods, and unpredictable weather patterns disrupt agricultural production, leading to food shortages and increased food prices. Armed conflicts, displaced communities, disrupted farming activities, and limited access to food and humanitarian aid, exacerbate malnutrition. Many households live below the poverty line, affecting their ability to purchase nutritious food, healthcare, and clean water. High unemployment rates also limit families' financial resources, reducing access to food and healthcare. Early cessation of breastfeeding, lack of exclusive breastfeeding, and inappropriate complementary feeding contribute to malnutrition in infants and young children. Diets often rely on staple foods like maize, rice, or cassava, with insufficient fruits, vegetables, and protein sources. High prevalence of diseases such as diarrhea, malaria, and respiratory infections increase nutrient loss and reduce food intake. Lack of access to clean water, sanitation facilities, and hygiene practices leads to frequent infections, particularly in children. Poor access to healthcare services, including maternal and child healthcare, contributes to malnutrition due to unaddressed health conditions and lack of nutritional guidance. Many communities lack knowledge about proper nutrition, leading to poor feeding practices.

3.2 Impacts of Malnutrition

Malnutrition is a leading cause of death in children under five, contributing to nearly half of all child deaths in Africa. Stunting and micronutrient deficiencies impact cognitive abilities, school performance, and future economic productivity. Malnourished individuals have weakened immune systems, making them more susceptible to infections. Malnutrition impedes economic growth by reducing workforce productivity, increasing healthcare costs, and perpetuating cycles of poverty.

Addressing malnutrition in Africa requires a multi-sectoral approach involving governments, non-governmental organizations, communities, and international bodies working together to create sustainable solutions.

According to FAO (2023), about 1 out of 600 million people or 1 in 2 of the world's total population are regularly starved of protein- particularly of animal protein. As you can see, Nigeria recorded roughly per capital protein intake of 51.7 grammes daily of which only 8.6 grammes came from animal sources as against a minimum requirement of animal protein of 35 grammes. In contrast, the average protein consumed per capital, per day in the developed countries totals over 90 grammes with more than 65grammes being of animal origin. The average calorie intake of our country is about 2,000 which is far below the average intake in some industrialized countries such as the U.S.A (3000 calories). The population of the developing countries, which bear the brunt of the calorie and protein deficiency-sometimes called 'protein calorie' or 'protein energy malnutrition' are children of the pre-school age (FAO, 2023).

The Prevalence of Undernutrition (PoU) in Africa rose from 19.4 percent in 2021 to 19.7 in 2022, basically driven by increases in northern and southern Africa. The number of people facing hunger in Africa has increased by 11million people since 2023 and by more than 57 million people since the outbreak of the pandemic. Many countries in the world, including Nigeria, are facing serious food crises and challenges. Hunger has been on the rise and it has been unabated in Nigeria and most **African countries** since 2010, with an unusual or uncommon increase in all sub-regions. Moreover, hunger increased throughout all sub-regions of Africa in 2022. The PoU in North Africa rose from 6.9 percent to 7.5 percent, equivalent to nearly 2 million more people facing hunger in 2022. In sub-Saharan Africa, hunger increased from 22.2 percent to 22.5 percent, which translates into 9 million more people compared to 2021. All sub-regions in Africa registered either a prevalence or a number of undernourished people well above pre-pandemic levels. Some countries in sub-Sahara region are: Ethiopia, Uganda, Ghana, Niger, Benin Republic, Nigeria, Mali, Cameroon etc.

Figure 3: Undernourishment by regions
Source: The Food Security Information Network (FSIN) collected data on how many people are in a food crisis across 6 primary regions (2023).

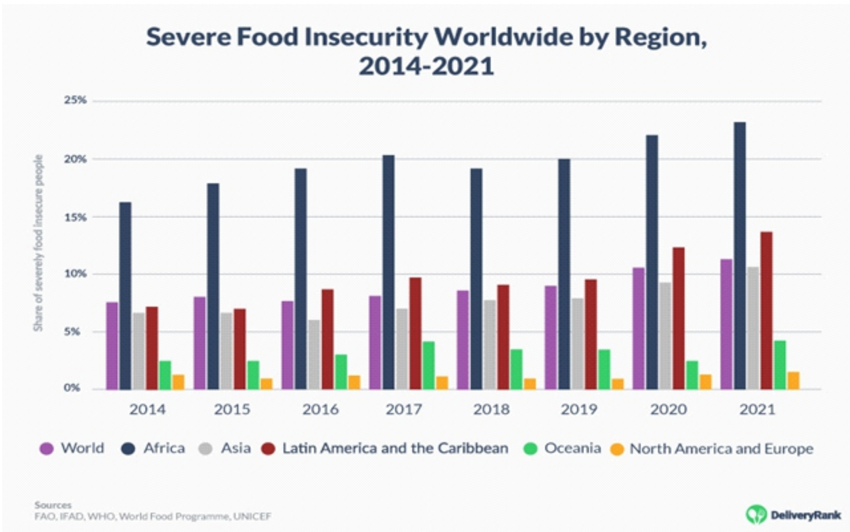

Figure 4: Severe food insecurity worldwide by regions 2014-2021
Source: Food and Agriculture Organization of the United Nations Rome, Italy (2024): Markets and Trade Division - Economic and Social Development Stream
FAO-Dairy-Outlook@fao.org

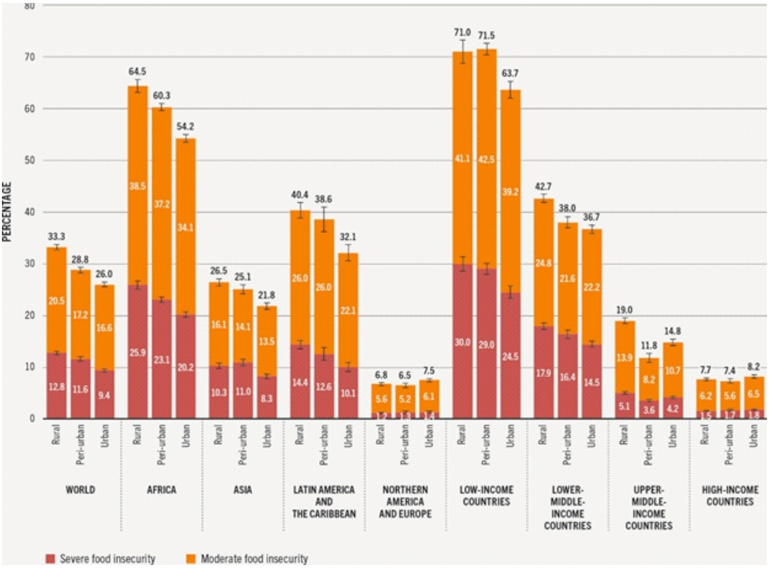

Figure 5: The Prevalence of Undernutrition (PoU) of the world as at 2023
Source: Food and Agriculture Organization of the United Nations Rome, Italy (2024): Markets and Trade Division - Economic and Social Development Stream
FAO-Dairy-Outlook@fao.org.

Figure 6: Broiler chicks at starter phase

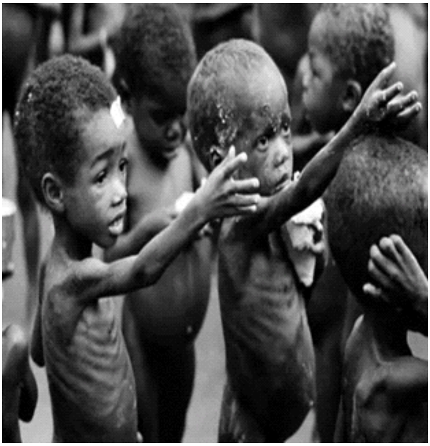

Figure 7: Malnourished African children
Source: WFP/Michael Tewelde

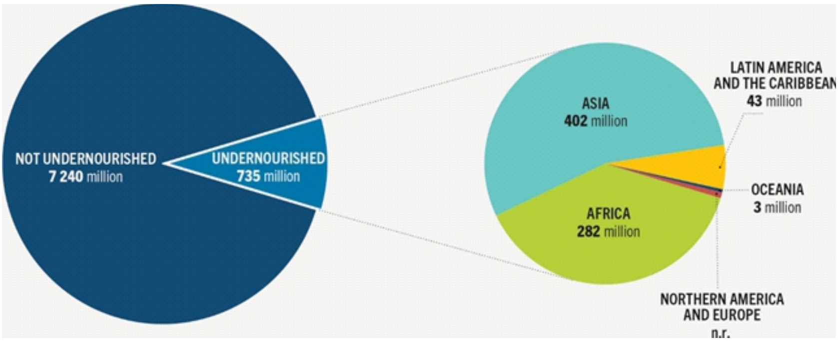

Figure 8: Undernourishment according to regions
Source: FAO, 2023. FAOSTAT: Suite of food security

Figure 9: A family was feeding their cows straws plucked from the roof of their home in Adadle in the Somali region of Ethiopia.
Source: WFP/Michael Tewelde

Figure 10: A dead animal that suffered from malnutrition
Source: Source: WFP/Michael Tewelde Adadle, in Ethiopia's Somali region 2022.

	Number of undernourished people (millions)									
	2005	2010	2015	2016	2017	2018	2019	2020*	2021*	2022*
WORLD	**793.4**	**597.8**	**588.9**	**586.4**	**571.8**	**586.8**	**612.8**	**701.4**	**738.9**	**735.1**
AFRICA	**178.2**	**159.2**	**189.6**	**204.1**	**207.9**	**215.6**	**225.1**	**254.7**	**270.6**	**281.6**
Northern Africa	11.7	9.8	12.3	13.4	14.4	14.6	14.4	15.1	17.6	19.5
Sub-Saharan Africa	166.5	149.5	177.3	190.7	193.5	201.0	210.6	239.6	253.0	262.0
Eastern Africa	94.2	81.5	96.8	106.1	108.6	110.8	116.9	126.4	131.2	134.6
Middle Africa	36.3	30.1	36.7	40.1	39.8	42.3	44.4	51.0	54.2	57.0
Southern Africa	2.8	4.2	5.9	5.3	5.1	5.1	5.5	6.4	6.8	7.6
Western Africa	33.2	33.6	37.9	39.2	40.1	42.9	43.8	55.8	60.8	62.8
ASIA	**551.9**	**392.8**	**357.8**	**336.0**	**319.3**	**325.2**	**343.9**	**396.2**	**414.1**	**401.6**
Central Asia	8.2	4.2	2.8	2.6	2.5	2.2	2.0	2.5	2.4	2.3
Eastern Asia	104.2	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
South-eastern Asia	97.6	66.7	47.9	41.6	37.4	36.5	35.0	35.2	36.0	34.1
Southern Asia	325.4	267.9	260.3	242.8	232.2	236.2	258.6	307.7	326.0	313.6
Western Asia	16.6	15.4	24.1	27.0	27.0	28.7	29.1	30.0	29.6	31.6
Western Asia and Northern Africa	*28.3*	*25.2*	*36.3*	*40.4*	*41.3*	*43.3*	*43.6*	*45.1*	*47.2*	*51.2*
LATIN AMERICA AND THE CARIBBEAN	**51.9**	**36.7**	**32.9**	**38.2**	**36.6**	**37.9**	**36.0**	**42.3**	**45.6**	**43.2**
Caribbean	7.4	6.1	5.6	5.8	5.7	6.1	6.2	6.7	6.5	7.2
Latin America	44.6	30.6	27.3	32.4	30.9	31.8	29.8	35.6	39.1	36.0
Central America	11.7	10.6	11.2	10.5	10.4	10.5	9.0	8.5	8.9	9.1
South America	32.8	20.0	16.1	21.9	20.5	21.3	20.8	27.1	30.3	26.8
OCEANIA	**2.3**	**2.4**	**2.5**	**2.5**	**2.5**	**2.7**	**2.8**	**2.7**	**2.9**	**3.2**
NORTHERN AMERICA AND EUROPE	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**	**n.r.**

Table 11: Populations of people suffering from malnutrition in different regions of the world
Source: FAO, 2023. FAOSTAT: Suite of food security

3.3 OVERVIEW OF THE LIVESTOCK SYSTEM: PATTERNS, PERFORMANCE AND CHALLENGES

DEFINITIONS:

Waste refers to any substance, material, or by-product that is no longer wanted, has no further use, or is considered useless, defective, or of no value. It typically requires disposal or management to minimize its impact on the environment. In order to shed better illumination, in my own case as an Animal Scientist, a waste (Agro Industrial by Products) can be considered from the following schools of thought:

1. A material or substance is said to be a waste when a process, be it chemical, microbial or industrial cannot transform the material or substance further due to lack of technical know-how, capability, lack of interest or financial strength.
2. **Agro-industrial by-products** are secondary products or residues generated during the processing of agricultural and industrial raw materials, such as crops, livestock, and other biological resources. These by-products are often considered waste but can be valuable resources when effectively managed or processed. They have various applications, including animal feed, fertilizers, biofuel production, and as raw materials in other industries (Ahmed et al; 2024).

3.4 Common Agro-Industrial By-Products

The outer layer of grains such as wheat, rice, and oats, removed during milling is rich in fiber and often used in animal feeds or as a dietary supplement. The outer shell of rice grains removed during processing is used as fuel, in construction materials, or as a growing medium in horticulture. Residues from corn plants, including cobs, leaves, and stalks, are used for animal feed, bioenergy production, and as organic mulch. The residues left after oil extraction from seeds like soybeans, sunflower, cottonseed, and groundnuts are high in protein and commonly used as animal feed. A by-product of palm oil processing is used in livestock feeds, particularly for ruminants. Leftover material from fruit and vegetable processing (e.g., citrus peels, tomato pulp) are used for animal feed, composting, or extracting essential oils and pectin. The fibrous residue remaining after sugar extraction from sugarcane, is used as fuel for power generation, paper production, or animal feed. A viscous by-product of sugar production from sugarcane or sugar beets, is commonly used as a feed ingredient, in fermentation industries (e.g., alcohol production), or as a soil conditioner (Muir & Anderson 2022). Residual grain from beer production, is used as livestock feed due to its high protein and fiber content. A by-product of ethanol production from grains, is widely used in animal feed, particularly for cattle. The liquid remaining after milk has been curdled and strained, is rich in lactose, vitamins, and minerals. It is used in animal feed, as a nutritional supplement, or in food processing. By-products of slaughterhouses used as high-protein animal feed supplements and fertilizer. A by-product of fish processing, is used as a high-protein feed ingredient for livestock and aquaculture. A by-product of cotton processing is used in animal feed and as a substrate for mushroom cultivation. The fibrous husk of coconuts, is used in horticulture as a growing medium, or for manufacturing ropes and mats (Sunho *et al.,* 2024).

3.5 Benefits of Utilizing Agro-Industrial By-Products

Converting by-products into useful commodities can create additional streams of income for farmers and processors. Effective use of by-products reduces environmental pollution and waste management costs. Maximizing the use of all parts of agricultural raw materials supports sustainable agriculture and circular economy principles. By-products used in animal feed can enhance nutrition and reduce the reliance on conventional feed ingredients. Agro-industrial by-products represent an opportunity to enhance sustainability in agriculture and industry by turning potential waste into valuable resources (Arnau *et al.,* 2024; Mohamed *et al.,* 2023).

3.6 Improvement of the Agro-Industrial By-products

Improving Agro-Industrial By-products for animal feeding is essential for enhancing the nutritional value, safety, and digestibility of the materials. The effective utilization of the by-products not only reduces waste but also lowers feed costs and supports sustainable livestock production (Sun et al., 2024).

What does improvement suggest?

a. there is standard nutritional value or status for materials or ingredients but the materials in/of reference has poor or low

Nutrient Recycling: the use of by-products in animal feeding helps recycle nutrients within the agricultural system, enhancing overall resource efficiency. Improving agro-industrial by-products for animal feeding is a win-win approach that supports sustainable agriculture, reduces costs, and enhances the nutritional management of livestock. Therefore, the essence of upgrading any material is to improve the nutritional value or quality (digestibility) of the material. Hence, wastes from agronomic practices like crop residues which are usually fibrous, lignified, cellulosic with little or low nutritional value can be upgraded (i.e. their value can be improved). The quality of a fibrous ingredient becomes improved when the fibre is broken down or digested or hydrolyzed into its component disaccharides (maltose, lactose or sucrose) and monosaccharides (glucose, galactose, fructose, mannose etc.) which can be digested, made bio-available , absorbable and utilizable or metabolizable to supply energy to the animal to which it is fed. Improved digestibility, bioavailability of nutrients, improved presentation in terms of colour, odour, texture etc., increased quality and status of digestible nutrients (carbohydrate, protein and lipid), increased absorption of digested materials, higher utilization and subsequent higher performance of animals in terms of meat and eggs are evidences that the material has been upgraded (Cuchillo-Hilario et al.,2024). If crop residues are fibrous materials, then a knowledge of how fibre is formed and its composition may make us to appreciate its nutritional and anti-nutritional values, how best to handle it, essence of treating and processing it and the consequences of treating or processing fibrous materials. Fibre is one of the many thin threads (fibrils) that form natural materials such as wood and cotton. It is equivalent to roughages which is also equivalent to dietary fibre. It is part of food. It is a dead cell in which the cell walls are heavily thickened with deposits of lignin (a hard substance, a physico-chemical binder) that provides mechanical strength wherever it is found. Fibre consists largely cellulose or cellulose fibrils which consists of structural polysaccharides (and lignin) which serve biologically as storage forms of monosaccharaides while others serve as structural elements in cell walls. Incorporating fiber into diets is crucial for maintaining optimal digestive health, regulating metabolic functions, and supporting overall well-being in both humans and animals. Its benefits range from improved gut health and weight management to enhanced nutrient absorption and disease prevention. For animals, fiber is nutritional value as at the time of consideration and because of this reason, its nutritional value or quality needs to be increased or improved,

b. if appropriate efforts/steps could be taken to treat or process the material, it can be used in the same or other systems or in some other ways,
c. the material can fit into some particular production processes but for its low nutritional status before upgrading,
d. the material is not useless outright after all but if it can be manipulated, processed treated or presented in another form. It has some nutritional potential/value and
e. alternative use(s) could be established or found for the material.

Improvement can also imply that:

I. the protein and the energy contents of the material in/of reference is low in digestibility or low in bioavailability, low in acceptability, or palatability,
II. the material contains chemicals or microbial contaminants which may constitute health hazards and
III. the feeding value of the material may be enhanced or improved or increased Benefits of Improving Agro-Industrial By-Products for Animal Feeding

1. **Cost Reduction**: utilizing improved by-products can significantly reduce feed costs, making livestock production more economical.
2. **Enhanced Animal Performance**: improved digestibility and nutrient availability lead to better growth, health, and productivity in animals (Cuchillo-Hilario *et al*., 2024).
3. **Sustainable Livestock Production**: efficient use of by-products reduces waste and promotes a circular economy in agriculture, contributing to environmental sustainability.
4. **Waste Management**: converting by-products into valuable feed reduces environmental pollution and the burden of waste disposal.

particularly important in ruminant diets, promoting efficient digestion and reducing feed costs through the utilization of fibrous by-products (Sun and Dou, 2024). By including fiber, we support not only health but also sustainability and economic efficiency in food production systems. On complete hydrolysis with the aid or by the action of specific enzymes, polysaccharides which form bundles of fibre yield monosaccharides (sugars) or their derivatives. At times, polysaccharides are called glycans which possess or differ in the nature of recurring monosaccharides units with respect to length of chains and on the degree of branching. Polysaccharides may be found as:

a. homopolysaccharides which contains a single type of monosaccharides unit for example starch (a storage carbohydrate) in plant cells and glycogen in animal cells and
b. as heteropolysaccharides which contains two or more different kinds of monosaccharide units. Starch itself contains two types of glucose polymers such as (i) α-amylose which has long unbranched chains (linear polymers) of glucose units which are connected by α (1-4) linkages/bonds. The chains in the α-amylase vary from a few thousands to five hundred thousand units of monosaccharides (glucose); (ii) amylopectin which has high molecular weight (mass) and is highly branched. Its glycosidic linkages that join successive glucose residues are α-(1-6) linkages. Cellulose (another example of polysaccharides) is the most abundant structural polysaccharides) it is the most abundant structural polysaccharide found in (i) cell walls of unicellular micro-organisms (SCP-single cell protein), (ii) higher plants, (iii) outer surface of animal cells and (iv) connective tissues of vertebrates.

It may not be reasonable for man to discard fibrous materials which house/store thousands or millions of glucose (sugar) units. The fibrous condition or form should just be seen as one of nature's design to store, pack, or bundle one of the many products of photosynthetic activity of plants. The energy or fuel preserved in fibrous materials cannot and need not be dismissed with a wave of hands because it is bound, tied, or twined by lignin. Note that fibre is a pack of polysaccharides which is a pack of glucose or other monosaccharides units which is a pack or unit of fuel or energy (Gericke, *et al.,* (2024).

3.7 Status of Fibre in Diets of Animals

While dietary fiber has many benefits, it can also have anti-nutritional effects, particularly in animal diets, if not properly managed. Plant fibers can be considered as composite structures of oriented cellulose fibrils embedded in a matrix of more or less rigid structures formed by the hemicellulose and lignin polymers. Important characteristics for fiber cells are determined by the amount and the distribution of the chemical constituents in various layers of the cell wall. Through immunocytochemistry, the cell wall components can be localized. General distribution of most fiber components is similar to that of any plant cell with a secondary cell wall. Pectins are localized mainly in middle lamellae and primary cell wall (though they may also be tightly associated to secondary cell wall cellulose). The secondary cell wall is highly enriched in cellulose. While nutrients are present in the lumen of agro-industrial by-products, they may be encapsulated by cell walls, making them less accessible unless the walls are disrupted (Saha *et al.,* 2024). Agro-waste to Microbe Assisted Value Added Product: Challenges and Future Prospects: Recent Developments in Agro-waste Valorization Research. Agro-industrial by-products often contain nutrients that are encapsulated within the cell wall of plant materials. Many of these by-products, such as bran, seed hulls, or pulp, contain fibrous components like cellulose, hemicellulose, and lignin that make up the cell wall. These structures can encase nutrients such as proteins, lipids, starches, and various micronutrients (like vitamins and minerals). However, these nutrients may not always be readily available for digestion or absorption, particularly by monogastric animals (e.g., humans, pigs and poultry), due to the physical barrier presented by the cell wall. Ruminant animals (e.g., cows, sheep), which have specialized digestive systems, are better equipped to break down these fibrous components through fermentation in the rumen. In agro-industrial processes, treatments such as milling, enzymatic hydrolysis, fermentation, or chemical treatments can be used to break down the cell wall structure, releasing the nutrients and increasing their bioavailability. These effects are mainly due to the indigestible nature of fiber, which can interfere with the absorption of essential nutrients, reduce the efficiency of feed utilization, and affect overall animal performance. Here is a detailed look at the anti-nutritional status of fiber in animal diets (Khajali and Rafiei, 2024).

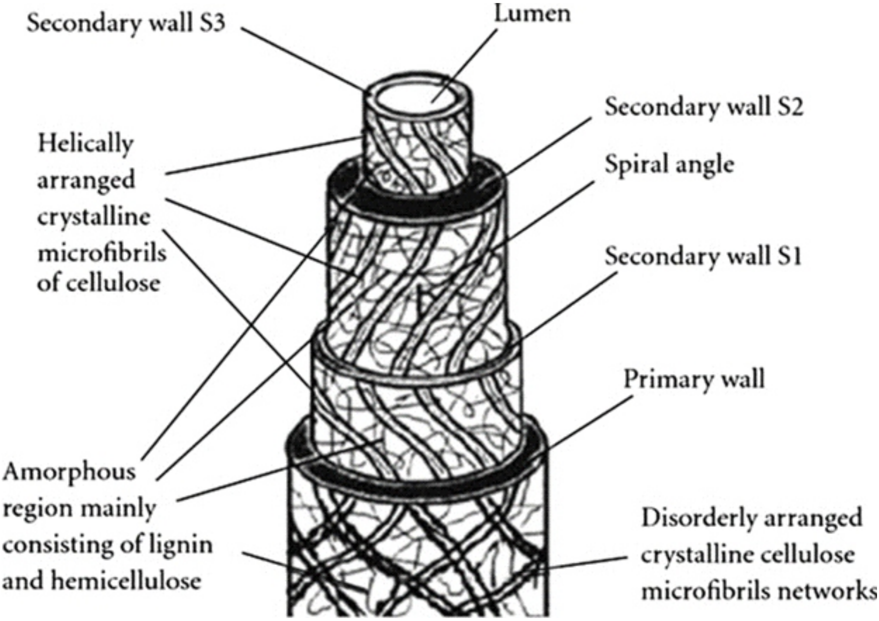

Figure 12: Structural organization of a natural fiber cell wall

Source: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/fiber-cells

High fiber content can bind with proteins and digestive enzymes, reducing the digestibility and availability of amino acids. This can limit the growth and production performance of animals, especially in monogastric species like pigs and poultry. Fibers, particularly those high in phytic acid, can bind essential minerals such as calcium, magnesium, zinc, and iron, making them less bioavailable. This can lead to mineral deficiencies in animals if not adequately managed. Fiber can trap fats and other energy-rich nutrients in the digestive tract, reducing their absorption and leading to lower energy availability. This is particularly problematic in young animals or those with high energy demands. Fiber increases the bulk of the diet, which can physically limit the amount of feed that animals can consume. This is especially critical for young or small animals whose digestive systems cannot handle large volumes of fibrous material (Maslanka *et al.,* 2023). High-fiber diets are often less palatable, leading to reduced feed intake. Animals may refuse fibrous feeds, which can result in decreased nutrient intake and poor growth performance. High fiber levels can speed up the passage of feed through the digestive system, reducing the time available for nutrient absorption, particularly for energy, protein, and vitamins. In poultry, soluble fibers can increase the viscosity of the gut contents, which slows down nutrient absorption, disrupts normal gut function, and can lead to poor feed conversion efficiency. Lignin, a complex polymer found in many fibrous plant materials, is completely indigestible and can bind to other nutrients, further reducing their availability. High lignin content is often associated with poor digestibility and feed efficiency. Some fibrous feeds contain anti-nutritional compounds like saponins and tannins, which can reduce protein digestibility and interfere with normal digestive processes. Phytates, common in cereal by-products, bind to phosphorus and other minerals, making them less available for absorption and utilization by animals, particularly non-ruminants. In ruminants, excessive fiber fermentation can lead to excessive gas production and conditions such as bloat, which can be detrimental to animal health (Chetan *et al.,* 2024). In some cases, microbial fermentation of fibers can produce anti-nutritional compounds, which can disrupt gut health and lead to conditions like diarrhea, particularly in young or stressed animals. The digestion of fiber requires more energy due to increased chewing, salivation, and microbial fermentation, leading to higher maintenance energy requirements and lower net energy available for growth or production. High-fiber diets lead to greater fecal bulk, which can increase water and nutrient losses, as well as the energy expended on defecation. Animals on high-fiber diets often exhibit slower growth rates due to reduced nutrient intake and utilization, particularly protein and energy. For lactating animals and poultry, high fiber can lower the efficiency of nutrient use, resulting in reduced milk yield and egg production. Fiber's impact on nutrient availability can affect reproductive performance, including reduced fertility and lower birth weights in offspring (Islas-Fabila *et al.,* 2024). Monogastric animals lack the microbial populations needed to break down high levels of fiber, making them particularly susceptible to the anti-nutritional effects of fibrous feeds. Soluble fibers can form gels in the gut, impairing nutrient absorption and affecting overall digestive efficiency. In summary, fibre demonstrates the following characteristics:

a. it has an abrasive nature.
b. it is bulky.
c. it is gritty(as found in palm kernel cake).
d. it impacts low density on diets containing high fibre content.
e. its composition vary from one plant species to another.
f. it is capable of sequestering (keeping away/preventing) water.
g. it is found in foods as soluble and insoluble dietary fibre.
h. its content of foods/feeds can be used to classify/index food/feed, and
i. based on location, it may be structural (consisting of insoluble lignin, cellulose, hemicellulose, soluble hemicellulose and other polysaccharides) or non-structural (soluble pectin, gums and mucilages).

While fiber plays an essential role in animal diets, it can also have the above limiting factors. Understanding these effects and employing appropriate processing and dietary strategies can help optimize the benefits of fiber, ensuring that it contributes positively to animal health and productivity rather than hindering it.

Mr. Vice-Chancellor, Sir, my attention is on the biotechnological method of optimizing the fibrous materials. Hence, I will like to shed light on this method.

Biotechnology refer to the use of living cells, bacteria and other biological organisms in industry and scientific processes. Biotechnology is an old technology e.g. wine making by Egyptians since 4000BC, as well as our fufu, ogi and iru fermentation. In general terms, it is the application of scientific and engineering principles to the processing of materials using biological agents to provide goods and services.

3.8 What are Enzymes?

Enzymes are biological macromolecules capable of accelerating the rate of reactions by factors as much as a million or more over the uncatalyzed reactions and are themselves not consumed in the process. They drive processes of life in all living things because most of reactions in living things do not take place at an appreciable rate without enzymes. Life is about chemical reactions and chemical reactions in living organisms are about life, all of which are catalyzed by enzymes. In other words, enzymes are catalysts hastening or quickening reactions and they are produced by cells of living organisms. Enzymes are vital biological catalysts that facilitate almost all biochemical reactions necessary for life (Kissman *et al*., 2024). Their specificity, efficiency, and ability to function under mild conditions make them indispensable in both natural biological processes and numerous industrial applications. Whenever enzymes are added to the diets, animals to which such diets are given derive many benefits and some of the benefits are listed below:

1. enzymes make animals grow faster and less vulnerable to diseases (Shkromada *et al.,* 2024).
2. enzymes improve efficiency of feed utilization.
3. enzymes are used to maximize the potentials of non-starch polysaccharides (NSP) by preventing gel formation (i.e. enzymes digest or breaks the α (1-6) bonds in NSP. Hence, they make glucose (monosaccharides) units available for energy production in the animals.
4. enzymes break the cell walls of plants.
5. when enzymes are added to animal diets, they usually lead to increase in performance of such animals.
6. addition of enzymes to diets is nutritionally beneficial to the animal and financially rewarding to the farmers or users (Akintan *et al*.,2024)

3.9 HOW MY ROMANCE WITH ENZYMES STARTED

Mr. Vice-Chancellor Sir, in the year 1999, I returned to the Department of Animal Science in the University of Ibadan for my M.Sc. programme and I was supervised by the late Prof. O. O. Tewe who incidentally happened to be the first Dean of Faculty of Agriculture, Bowen University. He called me into his office after my M.Sc. in University of Ibadan and he told me that I must work on enzyme related field for my Ph.D research work. He said “Tunde, pursue enzymology”. That was all I needed to hear. It sets me on fire for the work. I was initiated and birthed into enzyme research by Prof. Eustace Iyayi (a scion of Prof. Tewe). Upon the completion of my M.Sc., I approached Prof. Iyayi for Ph.D supervision and he jokingly asked me if I was ready to drink from the cup where he drank? I responded in affirmative not knowing that I took a step of destiny that day. Then, research in enzyme use as part of animal feed was just coming up not popular because it has to do a lot with the understanding of how nutrients are modulated within the animal and under interrelated biochemical controls. My knowledge about enzymes then was very, very limited. I had been taught their ability to catalyze reactions in which they are not changed in the end in my Biochemistry classes but I had no first hand interactions with them as I had never worked on them. I carelessly responded to his question as I said “Yes Sir, I am ready to drink from the same cup”. This decision to drink from the same cup he drank led to studies, which resulted in our production of enzymes using the instrumentality of Solid State Fermentation.

Prof. Iyayi poured himself into me. He led me headlong into enzymology making me to do part of my work in Pharmaceutical Microbiology (courtesy of Prof. Bolanle A. Adeniyi) and Biochemistry (with Prof. O. A. Adaramoye). I was able to complete my doctoral work in record time because of very wonderful supports and encouragements that I received from my supervisor. Little did I know that I would talk about enzymes and their usefulness across the continents of the globe. After my doctoral programme, I had the opportunities of going for postdoctoral research works in two different universities and two different continents. All through, the motive has always been the use of enzymes for improvement of wastes for animal feed. Having studied previous works on the potentials of enzymes to enhance animal performance, my research activities were focused on them for years.

3.9.1 Enzymes as Enhancers of Livestock Productivity

Naturally, enzymes from fungi have the capacity to move reactions from one level to the other and they tend to enhance the substrate on which they grow. In animals, enzymes in the gastro-intestinal tracts promote digestion and metabolism. The principal problem of poultry in sub-Saharan countries today is the cost of feed ingredients. This challenge has reduced the rate of expansion of the poultry industry and has added to the low level of animal protein nutrition of their citizens. Attempts to reduce the high cost of feeds and therefore the cost of meat production have concentrated on using feeds formulated from available and cheap alternatives and unconventional feedstuffs (Iyayi, 2017). Research into the use of cheaper industrial by-products and wastes at various levels of dietary inclusion for poultry has therefore been intensified in the last few years to determine the efficiency of their utilization in terms of growth and production. There is the need to harness the potentials of agro-industrial by-products and other unconventional feed resources (Valladares-Diestra *et al.,* 2023). Ordinarily, poultry cannot utilize high fibre diets because it lacks the digestive framework that can elaborately digest large amounts of agro-industrial by-products. Stabnikova (2023) reported that fibrous agro industrial by- products (like rice offal (RO) plays an important role in the maintenance of the normal structure and function of the intestinal mucosa. However, other workers, (Mohanto and Aye 2024) implicated crude fibre as a factor depressing nutrient digestibility, absorption, bioavailability and utilization. Crude fibre entraps nutrients in insoluble complex which it forms in the cell wall of plants and this resists the digestion by the endogenous enzymes in the gastro intestinal tract (GIT) of poultry and other non-ruminant animals .Viscosity-promoting potential of crude fibre also reduces overall digestive and absorptive efficiency by preventing nutrients from being available at the absorptive site in the intestinal mucosa (Canibe *et al.,* 2022). There is therefore the need to render the non-starch polysaccharides (NSPs) in fibre utilizable by the animals. One of the ways to achieve this is through the instrumentality of biotechnological tool-solid state fermentation (SSF). Biodegradation of the agro industrial by products by fungi will lead to the production of enzymes which will in effect break specific linkages in the long chain polysaccharides, releasing substances which the endogenous enzymes of the monogastric animals can break down further so that the nutrients can be absorbed and utilized. In other words, fungal biodegradation of agro industrial by products complements the birds' digestive enzymes, working with them to improve their efficiency. Beneficial fungi have the potential of splitting the β-1, 4 linkages in the hemicellulolytic xyloglucans of their primary cell wall and thereby reducing the viscosity of the gut contents and enhancing nutrient absorption (Dhamchoe *et al.,* 2024).

3.9.2 What is the price of maize today per ton?

Figure 13: Maize and chicken

During the harvest time, between July and October yearly, the price of maize often decrease owing to rise in availability. On the other hand, during the planting season, the price will rise as supply nosedives. The latest update says price of maize in Nigeria (August 14, 2024) ranges between N550, 000 to N600, 000 in Nigerian Naira per tonne. Meanwhile, average maize price in the country as at August, 2023 only reached N480, 000 per tonne. The livestock subsector, primarily dominated by poultry, experienced a contraction of 30.57 percent in the first quarter of 2023 compared to 5.55 percent in the same period of 2022. This marked the second consecutive quarterly contraction, driving the sector into a recession after a 1.59 percent contraction in the fourth quarter of 2022. The above explains why many poultry farmers have parked up and sold their farms (possibly, they left the country in the spirit of "japa"). Presently, a crate of eggs goes for about N5, 000.00 depending on the location. It is by far higher in places like Lagos, Abuja and Port Harcourt. What then is the way out?

Mr. Vice- Chancellor, Sir, distinguished audience, I wish to inform you that for the first fifteen years of my academic career and research, chickens were my experimental animals. They became my pets. I later transited into the world of ruminants working with cattle and many people seated here have known me for cattle husbandry and management. I started working with cattle in the later part of my research odyssey. My contributions show that an end is in sight to problems confronting the animals. If they will end up in pots, the products must be saucy, juicy, friable, chewable, palatable, and convenient to swallow, and subsequently be beneficial nutritionally to the eaters at the least affordable price. Ladies and gentlemen, I invite you to come on board with me as I take you through some of the works that I have done.

4.0 MY CONTRIBUTIONS TO KNOWLEDGE

Mr Vice Chancellor, Sir, I started my academic career on the 1st of September,2002 in Bowen University when I was employed into the Department of Animal Science and Fisheries Management in the then Faculty of Agriculture as an Assistant Lecturer with my M.Sc. degree. I earned all my degrees from the Premier University, the University of Ibadan, Nigeria. I have made my very humble and modest contributions to the Research and Development (R&D), and this led to my promotion to the position of Professor on the 1st of October, 2018, and by the grace of God, known in the research field of Nutritional Biochemistry and Feed Technology. In today's lecture therefore, I will like to share my contributions to knowledge in the following three areas:
(1) Broilers, (2) Layers and (3) Ruminants (with emphasis on dairy animals).

Figure 14a: A featherless chicken

Figure 14b: **Featherless chickens** are a genetically modified breed of chickens developed to have no feathers. The idea behind developing featherless chickens was to create a breed that would be more suitable for hot climates and more efficient in meat production. However, these chickens must be well fed so that they can easily convert feed into flesh for human consumption. Hence, my research work.

4.1 Isolation of Fungi and Enzyme Extraction

Moving from commercial enzymes to the natural microbes from which they are produced, I paid very close attention in my research to the possibility of extracting enzymes in solid state from our tropical fungi for use in improving our feedstuffs for animal feeding. One major question that I asked was how pure enzymes locked in the entity of the microbes can be brought out! I therefore, with the consent of my Ph.D supervisor, Prof. E. A. Iyayi, in collaboration with Prof. Bolanle A. Adeniyi (Department of Pharmaceutical Microbiology, University of Ibadan) and Prof. O. A. Adaramoye (Department of Biochemistry, University of Ibadan) pursued this goal. The work was thrilling and intriguing. We were able to achieve a level of success as seen in Lawal *et al.,* 2010. I was able to obtain pure enzymes from fungi by using substrates to elicit the production of enzyme in solid state. *Aspergillus. niger, T. viride, R. stolonifer* and *M. mucedo* were obtained from the culture bank of the then Department of Botany and Microbiology, University of Ibadan. A sterile wire loop was used to collect the spores and the mycelia of the actively growing fungi. The spores were counted (Onilude and Osho, 1999) and mycelia were then inoculated on sterile Potato Dextrose Agar (PDA) in a lamina flow cabinet. The inoculated plates were incubated at 34°C in an incubator. After 48 hours when growth of the fungi on the plates was fully established, their pure cultures were then obtained and the mycelium put on slants of sterile PDA. With further treatment, as shown in the flow chart, we were able invent a system for the production and isolation of the crude and purified enzyme. This process is currently undergoing patent. The World Poultry Science Association acknowledged this work.

50 gm substrate + 20 ml basal medium + fungus

↓ Inoculation for 7 days at 34°C

Substrate-Fungus material (SFM)

↓ 100 ml 0.1M phosphate buffer pH 7.2

SFM-Buffer Mixture (SFM-BM)

↓ Mix + Filter through double layer muslin

Crude enzyme filtrate (CEF in ice cold flasks)

↓ Centrifuge at 3000 rpm, 4°C for 15 mins

Crude enzyme supernatant (CES)

↓ Dialysis against distilled H_2O for 12 hours

Purified enzyme extracts (PEE)

Flow chart of production of enzyme from isolated fungi (Lawal *et al.,* 2010)

Mr Vice-Chancellor, Sir, in 2017, I had the opportunity of securing a post-doctoral fellowship instituted and fully sponsored by INSA JRD TATA which I used at Centre for Biotechnology, Jawaharlal Nehru Technological University, Hyderabad, Kukatpally, Telangana State, India under a very hard working Indian scientist, Professor M. Narasu (a woman that knew her onions in enzymology). While in her laboratory, we worked on Endoglucanase (EC3.2.1.4) production by *Aspergillus niger, Trichoderma reesei* and *Rhizopus stolonifer* using agro industrial by-products. Agro industrial by-products (wheat offal, corn offal and groundnut pod) and cellulose were used as substrates for the production of endoglucanase (EC3.2.1.4) by *Aspergillus niger (A. niger), Trichoderma reesei (T. reesei)* and *Rhizopus stolonifer (R. stolonifer).* The optimum enzyme activity for *T. reesei* (0.75 unit mg protein^{-1}) was obtained at 72 h of cultivation, while *A. niger* (0.65 unit mg protein^{-1}) and *R. stolonifer* (0.51 unit mg protein^{-1}) gave their highest enzyme activities at 48 and 72 hours respectively when the fungi were incubated on cellulose for 96 hours. For the agro industrial by-products, maximum enzyme activity was obtained with groundnut pod where *A. niger*, *T. reesei* and *R. stolonifer* gave the maximum enzyme activity of 0.35, 0.30 and 0.29 units mg Protein^{-1} respectively after 144 h of growth. *A. niger* had the highest enzyme activity with any of the agro industrial by products followed by *T. reesei*. Hence, the study showed that the use of groundnut pod is the best among the agro industrial by-products for low-cost commercial production of endoglucanase using *A. niger*.

Figure 1 shows the differences in cellulase activities of *A. niger, T. reesei* and *R. stolonifer* when grown in cellulose media incubated for 96 hours. Maximum enzyme activity was realized from the culture broth of *T. reesei* at 72 hours of incubation and the enzyme activity was 0.75 Units mg protein^{-1}. Enzyme activity of *A. niger* was highest at 48 hours with an activity of 0.65 units mg protein^{-1} but that of *R. stolonifer* got to the peak at 36 hours of incubation and the value was 0.5 units mg protein^{-1}. Enzyme activities show two prominent peaks with *A. niger* and *T. reesei* during the 48 and 72 hours incubation periods respectively (Fig. 1).

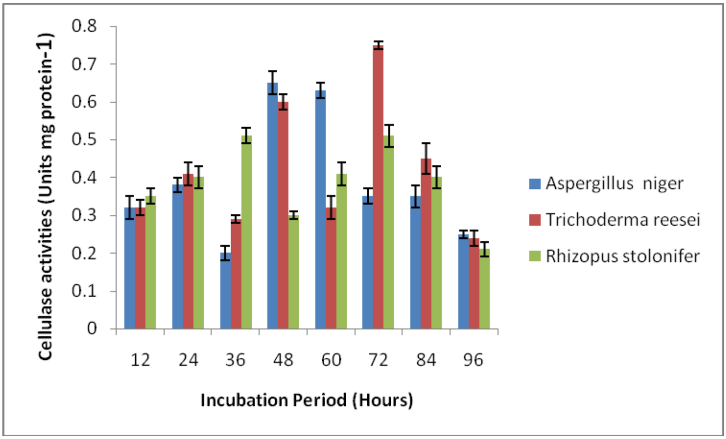

Figure 15: Cellulase activities of *A. niger, T. reesei* and *R. stolonifer* incubated in cellulose media for 96 hours.

Besides, for A. *niger*, the least activity was at 36th hour. The least activity for *T. reesei* (0.25 units mg protein^{-1}) occurred at 96th hours. Table I shows the extracellular protein obtained from *A. niger, T. reesei* and *R. stolonifer* incubated with different agro industrial byproducts. More proteins were obtained from the use of AIBs than the pure crystalline cellulose.

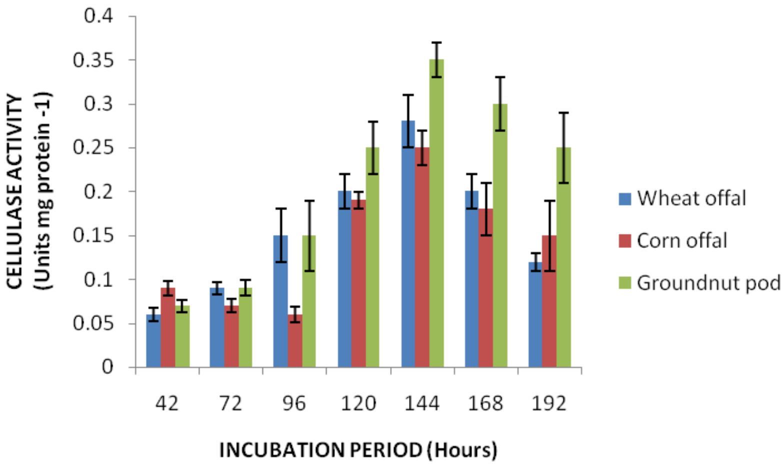

Figure 16: Cellulase activities of *A. niger* incubated on wheat offal, corn offal and groundnut pod for 192 hours. The maximum cellulase activity of 0.35 unit mg protein^{-1} was observed with groundnut pod during 144 hours of growth. The highest cellulase activities value for corn offal and wheat offal were 0.25 and 0.30 unit mg protein^{-1} respectively.

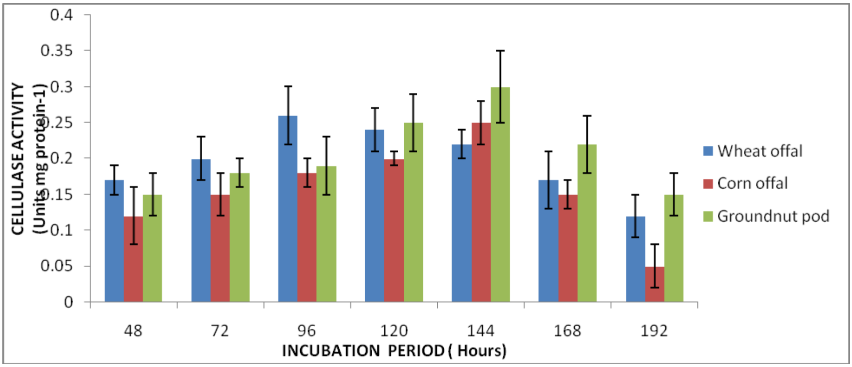

Figure 17: Cellulase activities of *T. reesei* incubated on wheat offal, corn offal and groundnut pod for 192 hours. Highest activity (0.29 unit mg protein^{-1} was obtained at 144hours when grown on groundnut pod while the least (0.05 unit mg protein$^{-1)}$ was recorded when T. reesei was cultivated on corn offal at 192 hours.

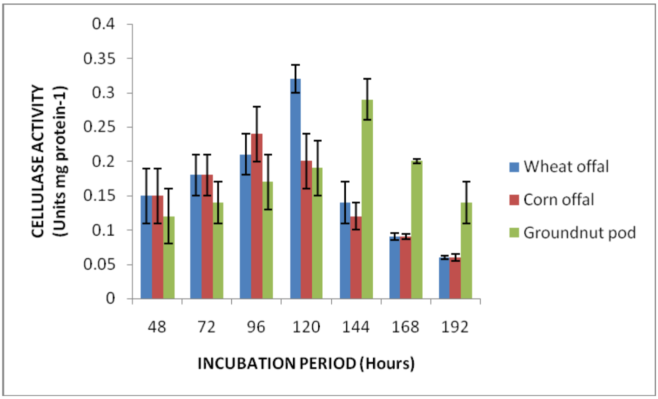

Figure 18: Cellulase activities of *R. stolonifer* incubated on wheat offal, corn offal and groundnut pod for 192 hours. Peak cellulase activity (0.33 unit mg protein^{-1}) was obtained with wheat offal at 120 hours. The maximum cellulase activity was followed by 0.29 unit mg protein^{-1} recorded at 144 hours when *R. stolonifer* was incubated on groundnut pod. Cellulase activities of *A. niger, T. reesei* and *R. stolonifer* incubated on groundnut pod containing media for 192 hours are shown in figure 5. *T. reesei* produced the highest amount of cellulase at 144 hours. The least amount (0.05 unit mg protein^{-1}) was observed with the *T. reesei* during the 48 hour. *A. niger, T. reesei* and *R. stolonifer* have the ability to produce endoglucanase from wheat offal, corn offal and groundnut pod. Among the three AIBs, groundnut pod recorded the highest yield of enzyme when *A. niger* and *T. reesei* were grown on it and it came second when *R. stolonifer* was cultured on the AIBs.

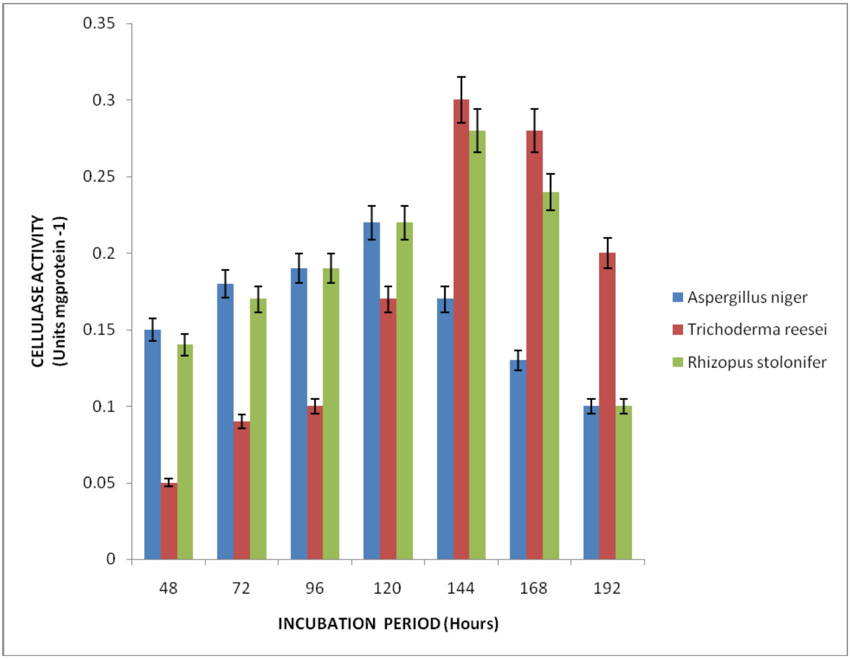

Figure 19: Cellulase activities of *A. niger, T. reesei* and *R. stolonifer* incubated on groundnut pod containing media for 192 hours.

From the foregoing, it is evident that these AIBs may be considered for the commercial production of endoglucanase. Moreover, their use will lead to production of cheaper cellulase and reduction of environmental pollution.

4.2 Chemical Analysis of Degraded and Undegraded Agro

Industrial By products

Further works of Lawal *et al*. (2008; 2010; 2011; 2012; 2013; 2016a; 2016b; 2017a; 2017b; 2020 and 2023) reveal that fungal biodegradation of AIBs via the instrumentality of solid state fermentation has the potential of reducing the crude fibre to the tolerable level to the monogastrics.

Table 4: Proximate and detergent fibre analysis of the undegraded and degraded wheat offal (g/100 gDM)

Parameters	Undegraded wheat offal	Degraded wheat offal
Dry matter	87.53	89.11
Crude protein	2.43	4.00
Ash	2.33	3.58
Ether extract	0.17	0.13
Crude fibre	11.60	8.35
Nitrogen free extract	84.14	86.19
Gross energy (kcal/kg)	4.73	5.86
Cellulose	8.12	6.55
Hemicellulose	5.33	4.23
Neutral detergent fibre	2.11	1.85
Acid detergent fibre	3.16	2.90
Acid detergent lignin	7.02	6.20

Table 5: Proximate and detergent fibre analysis of undegraded and degraded rice offal (g/100gDM)

Parameter	Undegraded rice offal (g/100gDM)	Degraded rice offal (g/100gDM)
Dry matter	88.68	90.03
Crude protein	8.79	12.42
Ash	10.31	12.78
Ether extract	0.14	0.12
Crude fibre	15.89	10.82
Nitrogen free extract	62.87	67.86
Gross energy (kcal/kg)	3.45	4.72
Cellulose	7.41	6.48
Hemicellulose	4.58	3.27
Neutral detergent fibre	2.41	1.35
Acid detergent fibre	6.13	4.23
Acid detergent lignin	3.85	2.14

Table 6: Proximate and detergent fibre analysis of test ingredients and diets (g/100gDM)

Parameters	UPPL	DPPL	DIET 1 0% PPL	DIET 2 7%UPPL	DIET 3 3%DPPL	DIET 4 5%DPPL	DIET 5 7%DPPL
%Dry matter	88.67	86.92	87.81	88.26	87.56	87.14	88.53
% Crude protein	8.92	13.86	18.11	18.23	18.38	18.27	18.14
% Crude fibre	14.81	10.27	3.81	3.41	3.85	3.53	3.16
% Ether extract	6.22	5.42	5.22	5.31	6.03	6.23	5.01
% Ash	6.47	7.95	17.65	17.73	18.20	17.89	18.22
(%)Nitrogen free extract	44.08	46.19	56.32	56.22	56.14	56.11	57.22
Gross energy (kcal/g)	4.28	5.25	3.68	3.51	3.22	3.61	3.76
Neutral detergent fibre	40.81	38.21	35.24	35.51	35.81	36.01	34.89
Cellulose	24.66	15.22	6.19	6.21	6.14	6.81	6.11
Hemicellulose	16.15	12.43	5.21	5.14	5.81	5.29	5.02
Acid detergent fibre	10.35	8.12	4.44	4.91	5.12	4.38	4.61
Neutral detergent lignin	14.31	11.61	8.18	8.71	8.22	8.42	8.43

UPPL=Undegraded plantain peel, DPPL= degraded plantain peel.

Table 7: Chemical composition of undegraded and degraded citrus pulp (g/100gDM)

Composition	Undegraded Citrus pulp	Degraded Citrus Pulp
Dry Matter	89.24	94.17
Crude Protein	14.10	16.14
Ether Extracts	4.17	3.74
Crude Fibre	8.15	6.41
Ash	4.61	5.11
NFE	58.21	61.31
Calcium	3.21	4.14
Phosphorus	0.64	0.72
Gross Energy (Kcal/kg)	2.88	3.79

Table 8: Proximate and detergent fibre analysis of undegraded and degraded brewer dried grain (g/100 gDM)

Composition	**UBDG (%)**	**DBDG (%)**
Dry matter	90.13	87.19
Crude protein	27.89	39.12
Ether extract	7.38	5.84
Ash	4.39	6.22
Crude fibre	14.85	11.17
Gross energy (Kcal/kg)	4.92	7.10
Cellulose	7.15	5.55
Hemicellulose	4.82	3.48
Neutral detergent fibre	2.45	1.47
Acid detergent fibre	2.66	1.79
Acid detergent lignin	5.16	4.27

The treatment of AIBs with the fungal enzyme extracts caused a significant reduction in the crude fibre and complex carbohydrate fractions and an increase in the crude protein, metabolizable energy and phosphorus in the AIBs compared to the undegraded AIBs. The amounts of glucose, fructose, galactose and sucrose in Degraded AIBs were significantly increased. Fungi are known to have the ability to colonize the carbon source for optimum utilization of the available nutrients in carbon source. Subsequently, they manufacture and produce considerable quantities of extra cellular enzymes that can affect the hydrolysis of nutrients to materials that can penetrate the fungi via the cell membrane to increase the fungal metabolic activities and this process will promote development of the fungus. Hence, development in growth and continuous multiplication of fungal body mass as single cell protein (SCP) may partly be responsible for the increase in the protein content after biodegradation. The process of solid state fermentation, apart from adding to the protein content, also adds monosaccharides into the medium owing to hydrolysis of unavailable non starch polysaccharides. This implies the production of enzymes in the medium that empowers them to break complex polymers. This probably further sheds light on the reasons for reduction in crude fibre content. The cell contents of AlBs are digestible but for the cell walls which consist primarily of cellulose and hemicellulose are poorly digested because they are highly lignified. The fungal enzymes have the potentials of improving not only the NSPs but also of protein as well as other dietary components, such as fatty acids. In addition, owing to the effect of fungal biodegradation, it has been observed that monogastrics tend to eat more and this translates into better body weight gain by the broilers. Besides, the birds do have better feed conversion ratio.

4.3 Feeding of Biodegraded Agro Industrial By-Products to Broilers

Positive Effects

1. **Improved Digestibility**: biodegradation of agro-industrial byproducts (e.g., using fungi, bacteria, or enzymatic treatments) breaks down complex fibers, cellulose, and anti-nutritional factors. This enhances the digestibility of these byproducts for broilers, allowing for better nutrient absorption.
2. **Cost-Effective Feed**: by incorporating agro-industrial byproducts into broiler diets, feed costs can be significantly

reduced. These byproducts are usually cheaper than conventional feed ingredients like maize or soybean meal, making broiler production more economically viable.

3. **Sustainable and Environmentally Friendly**: utilizing byproducts reduces agricultural waste, promoting environmental sustainability. It contributes to a circular economy by converting what would be waste into valuable resources for broiler nutrition.
4. **Health Benefits**: some degraded byproducts, depending on their source and processing, can have bioactive compounds like prebiotics, antioxidants, or antimicrobial properties. These compounds may improve gut health, boost immunity, and reduce the need for antibiotics in broilers.

Growth Performance: when appropriately formulated, degraded agro-industrial byproducts can support normal growth rates in broilers.

Parameters	uGNP	GNP +Tv	GNP +An	GNP +Rs	GNP +Mm	GNP +RG2G	SEM	p- value
Final weight at 8 weeks (g)	1321.12'	1631.42'	1532.37'	1516.1Qb	1497.1Qb	1397.20'	2.41	0.0001
Feed intake (g)	2972.76'	3665.76'	3371.76'	3278.52b	3155.D4b	3090.92'	40.14	0.0026
Feed conversion ratio	3.48	2.2	3.55	3.49	3.49	3.49	0.12	0.0030
Weight gain (g)	852.04'	1035.16'	950.32b	939.68b	903.B4b	885.92'	25.21	0.0040
% DM digestibility	78.81b	81.86'	81.35'	80.46'	78.96b	78.91b	0.54	0.00052

Means with different superscripts along the same *rc,w* are significantly different ($p<0.05$); An= *Aspergillus niger,* Tv = *Trichoderma viride,* Rs= *Rhizopus stolonffer,* Mm= *Mucor rnucedo,* RG2G = Roxazyme G2G

Table 10: Performance of broiler finishers fed undegraded and degraded plantain peel

Parameters	Control	7% UPPL	3% DPPL	5% DPPL	7% DPPL	SEM
Initial body weight(g/b)	410.00^{d}	390.00^{c}	480.00^{c}	510.00^{b}	560.00^{a}	10.15
Daily weight gained(g/b)	39.66^{d}	38.05^{d}	40.74^{c}	42.96^{b}	46.39^{a}	4.23
Final body weight(g/b)	1520.40^{d}	1455.44^{e}	1620.64^{c}	1712.76^{b}	1858.92^{a}	15.28
Weight gained at 4^{th} week	1110.40^{c}	1065.44^{d}	1140.64^{b}	1202.76^{a}	1298.92^{a}	12.14
Daily feed intake (g/b)	115.77^{b}	128.74^{a}	110.41^{c}	106.53^{c}	102.99^{d}	5.16
Final feed intake (g/b)	3241.56^{b}	3604.72^{a}	3091.48^{c}	2982.84^{c}	2883.72^{d}	19.12
Feed conversion ratio	2.92^{ab}	3.38^{a}	2.71^{b}	2.48^{b}	2.22^{b}	0.46
Nutrients digestibility (%)						
Dry matter	80.11^{c}	83.61^{b}	83.78^{b}	85.00^{ab}	88.72^{a}	3.23
Crude protein	68.45^{b}	68.13^{b}	72.36^{c}	75.49^{a}	76.80^{a}	2.95
Crude fibre	41.24c	43.24^{b}	45.24^{a}	42.57^{b}	46.81^{a}	2.67
Ether extract	64.82	64.81	64.74	64.58	64.21	0.00
Ash	52.79	53.10	52.79	52.79	53.11	0.00

Table 11. Performance of broiler finisher fed diets containing undegraded and degraded wheat offal

Parameter	Control	7% UWTO	3% DWTO	5% DWTO	7% DWTO	SEM
Body weight gain (g/b/d)	59.53^{c}	52.27^{d}	62.29^{b}	65.10^{a}	66.61^{a}	2.15
Feed intake (g/b/d)	167.81^{c}	171.53^{b}	168.79^{c}	181.58^{a}	181.21^{a}	8.39
Feed conversion ratio	2.81^{b}	3.28^{a}	2.70^{b}	2.78^{b}	2.70^{b}	0.017
Efficiency of feed utilization	0.35^{a}	0.30^{b}	0.36^{a}	0.35^{a}	0.36^{a}	0.005
Mortality (%)	1	0	0	0	1	
Relative cost benefit (%)	0.00	3.21	3.84	4.31	4.12	

^{a,b,c}, Means in the same row with different superscripts differ significantly (P<0.05);
UWTO = undegraded wheat offal; DWTO = degraded wheat offal.

Table 12: Performance of broiler finishers fed diets containing undegraded and degraded rice offal

Parameter	Control	7% URO	3% DRO	5% DRO	7% DRO	SEM
Body weight gain (g/b/d)	66.33^{d}	64.64^{e}	69.44^{c}	73.28^{b}	75.52^{a}	2.22
Feed intake (g/b/d)	177.66^{ab}	164.37^{c}	175.20^{b}	193.44^{a}	201.84^{a7}	7.41
Feed conversion ratio	2.67	2.54	2.52	2.63	2.67	0.0 15
Efficiency of feed utilization	0.37	0.39	0.40	0.38	0.37	0.0 04
Mortality (%)	1	0	1	0	1	-
Relative cost benefit (%)	0.00	5.12	5.92	5.88	5.41	-

a,b,c, Same row with different superscripts differ significantly (P<0.05);

URO, undegraded rice offal; DRO, degraded

Table 13: Performance of broiler finisher fed diets containing undegraded and degraded brewer dried grain

Parameter	Control	7% UBDG	3% DGDG	5% DBDG	7% DBDG	SEM
Feed intake (g/b/d)	91.07^{c}	81.43^{d}	93.57^{b}	102.5^{ab}	116.79^{a}	2.67
Body weight gain (g/b/d)	44.28^{d}	38.92^{e}	50.00^{c}	56.78^{b}	66.79^{a}	1.33
Feed conversion ratio	2.05^{a}	2.09^{a}	1.87^{b}	1.80^{b}	1.75^{c}	0.021
Mortality (%)	0	1	1	0	0	-
Relative cost benefit (%)	0.00	2.45	3.44	3.95	4.12	-

a, b, c, Means in the same row with different superscripts differ significantly (P<0.05);

UBDG=Undegraded brewer dried grains; DBDG=degraded brewer dried grains

4.4 Effects of Feeding Biodegraded Agro Industrial By-products on Haematological and Serum Biochemistry

Upon further investigations, Lawal *et al*. (2012a; 2012b and 2024) reported the effects of feeding the birds with degraded AIBs on haematological and serum biochemical parameters. The blood parameters such as the packed cell volume, haemoglobin concentration, white blood cell counts and red blood cell counts were not negatively affected by the degraded AIBs. Their values were within the normal range expected for the chickens.

Parameters	(Control) containing 0% PPL	7% undegraded PPL	3% degraded PPL	5% degraded PPL	7% degraded PPL	SEM
PCV (%)	28.11^{b}	26.20^{c}	29.14^{b}	29.82^{b}	20.51^{a}	0.31
Haemoglobin (%)	20.44	20.50	20.32	21.54	21.60	0.043
RBC (%)	2.63	2.96	2.80	2.97	2.99	0.03
WBC($x10^3/\mu l$)	25200	25985	25223	25431	25511	9.07
MCV(fl)	121.12	121.94	122.34	121.35	122.50	10.53
MCH(Pg)	42.11	41.54	42.36	42.45	42.01	0.46
MCHC (%)	33.14	33.19	32.46	32.51	32.22	1.38
Urea (ng/dl)	36.65^{a}	31.38^{b}	30.52^{b}	25.11^{b}	25.42^{c}	1.22
Total Protein(g/dl)	6.32^{c}	6.11^{c}	6.54^{c}	7.24^{b}	8.21^{a}	0.06
Albumin (g/dl)	2.81	2.85	2.80	2.82	2.80	0.09
Globulin(g/dl)	2.11^{c}	2.12^{c}	2.01^{c}	2.92^{b}	3.61^{a}	0.04
Arginine(g/dm)	0.78	0.81	0.82	0.81	0.79	0.003
Cholesterol (g/dl)	2.14^{a}	2.80^{a}	1.14^{b}	1.25^{b}	1.31^{b}	0.03
Triglyceride(mg/dl)	15.27^{b}	17.85^{a}	14.45^{c}	11.87^{d}	11.51^{d}	0.05
Glucose(mg/dl)	130.23^{b}	141.11^{a}	125.32^{c}	125.42^{c}	126.91^{c}	0.08

Table 14: Haematological and serum biochemical parameters for broiler finishers fed undegraded and degraded plantain peel

PCV=Packed cell volume, RBC=Red blood cell, WBC=White blood cell, MCV=Mean corpuscular volume, MCH=Mean corpuscular haemoglobin and MCHC=Mean corpuscular haemoglobin concentration.

Table 15: Haematological indices for layers fed undegraded and degraded citrus pulp

Parameters	Control	3% DCTP	5% DCTP	7% DCTP	3% UCTP	5% UCTP	7% UCTP	SEM
PCV (%)	26.00^{a}	26.50^{a}	27.00^{a}	26.50^{a}	25.50^{ab}	25.60^{ab}	25.00^{b}	0.06
Haemoglobin (g/100 ml)	7.63	7.83	7.34	7.50	7.85	8.05	7.73	0.03
Red Blood Cell ($10^6/\mu l$)	2.36	2.47	2.46	2.40	2.56	2.62	2.59	0.12
MCV (fl)	97.46^{a}	95.14^{b}	91.60^{c}	91.46^{c}	91.80^{c}	89.43^{d}	88.80^{d}	2.13
MCHC (gm/100 ml)	33.17	33.32	31.23	33.33	33.40	34.25	33.61	0.47
MCH (pg)	32.33	31.70	29.84	31.30	30.66	30.73	29.85	2.21
Total WBC ($\times 10^3/\mu l$)	8.45	9.50	8.20	8.75	9.05	9.15	8.90	0.75

Means with different superscripts along the same row are significantly ($P<0.05$) different.
DCTP=degraded citrus pulp and UCTP = undegraded citrus pulp; MCV= Mean Corpuscular Volume: PCV/RBC×10, MCHC= Mean Corpuscular Haemoglobin Concentration;
MCH= Mean Corpuscular Haemoglobin: Haemoglobin; WBC= White Blood Cell

Table 16: Serum biochemistry indices for layers fed undegraded and degraded citrus pulp

Parameters	Control	3% DCP	5% DCP	7% DCP	3% UCP	5% UCP	7% UCP	SEM
Total Protein (g/dl)	7.01^{ab}	7.49^{ab}	90.30^{a}	8.01^{ab}	6.63^{b}	6.54^{b}	5.24^{c}	0.09
Albumin (g/dl)	2.41	3.02	2.04	2.70	2.06	2.54	2.86	0.27
Creatinine (mg/dl)	1.88	2.15	2.20	1.98	2.68	2.73	2.58	0.03
AST (I.μ/L)	33.59	37.13	37.13	49.51	45.09	40.66	37.13	2.74
ALT (I.μ/L)	8.15	7.57	7.38	7.81	8.85	9.57	10.00	1.07

Means with different superscripts along the same row are significantly ($P<0.05$) different.
DCP=degraded citrus pulp; UCP=undegraded citrus pulp; AST= Aspartate aminotransferase;
ALT= Alanine aminotransferase;

In other collaborative work, Alabi et al. (2006) and Alabi et al.(2016), reported that the housing system has significant effects ($p<0.05$) on feed intake, final body weight, hen-day production, mortality rate, and egg weight, but not on the initial body weight and egg quality . In these works, deep litter system, conventional battery cage system, and extended battery cage system were used. We reported that deep litter system is the best way of housing chickens for now from a welfare point of view, particularly in situations where farmers are constrained to practice a free-range system.

Table 17: Performance characteristics of hen in different housing systems

	Treatment			
Parameters	PBC	EBC	DLS	SEM
Av. Daily feed intake (g/bird/day)	111.61^{c}	120.74^{b}	130.25^{n}	0.45
Av. Initial body weight (kg)	1.48	1.50	1.50	1.005
Av. Final body weight (kg)	1.78^{a}	1.76^{a}	1.69^{b}	0.15
Av. Body weight change (kg)	0.30^{a}	0.26^{b}	0.19^{c}	0.03
Av. Hen daily lay (%)	75.01^{a}	74.49^{a}	71.52^{b}	0.40
Feed conversion ratio	2.05^{c}	2.10^{b}	2.37^{a}	0.11
Cost of feed/dozen eggs (N)	68.50	68.75	74.75	
Mortality (%)	5.55	5.55	11.11	

Means along the same row with the same superscript are not significantly different ($p>0.05$)
PBC= partitioned battery cage (conventional); EBC= extended battery cage; DLS= deep litter system

Table 18: Egg quality characteristics of hens in different intensive housing systems

Parameters	PBC	EBC	DLS	SEM
Egg weight (g)	63.13^{a}	62.85^{a}	60.07^{b}	0.10
Shell thickness (mm)	0.38	0.39	0.38	1.01
Albumen weight (% egg weight)	63.93	63.71	63.53	0.54
Yolk weight (% egg weight)	23.73	23.58	23.44	0.60
Haugh Unit (%)	74.30	74.12	73.98	0.10
Yolk length (cm)	4.12	4.12	4.11	0.05
Yolk diameter (cm)	1.57	1.57	1.58	0.02
Yolk index	0.38	0.38	0.38	

Means along the same row with the same superscript are not significantly different ($p>0.05$)

PBC= partitioned battery cage (conventional); EBC= extended battery cage; DLS= deep litter system

In other works, we investigated the use of plant extracts as an additive to chicken feeds. Fluted pumpkin (*Telfaria occidentalis*) is known to be rich in minerals (Ayoola *et al*., 2010; Ladokun *et al.*, 2013) and we therefore exploited its usefulness in poultry nutrition. Alabi *et al*. (2008) reported that *Telfaria occidentalis* leaf extract will improve the growth rate of broiler chickens and also improve the carcass yield and the packed cell volume of the blood at the finisher phase with no adverse effect on the chickens.

Table 19: Effect of Replacing Maize with Indomie Noodle Waste Meal in the Diets of Broiler Finishers on the Hematological Parameters

Treatments						
Parameters	1	2	3	4	5	SEM
Hb (g/dl)	9.20[a]	8.50 [a]	9.20 [a]	8.80 [a]	7.50[b]	0.70
Packed Cell Volume (%)	29.00 [a]	27.00 [a]	29.00	28.00	25.00[b]	2.50
White Blood Cells (103/µl)	2.00	2.10	2.10	1.90	2.00	0.30
Red Blood Cells (106/µl)	2.65	2.67	2.65	2.68	2.65	0.20
MCH (Pg)	3.47[a]	3.18[a]	3.47[a]	3.28 [a]	2.83[b]	0.30
Mean Cell Volume (fl)	10.49[a]	10.11[a]	10.94[b]	10.44[a]	9.05[b]	0.85
MCHC (%)	31.00	31.00	32.00	31.00	31.00	2.00

abcd: means with different superscripts are significantly different ($p < 0.05$)
SEM: Standard Error of Mean; MCH= Mean corpuscular hemoglobin;
MCHC= Mean corpuscular hemoglobin concentration

Along the same line, some spices were reported to have probiotic activities in monogastric nutrition and this prompted us to investigate their tolerable level of inclusion.

Table 20: Effect of moringa leaf powder on serum cholesterol fractions of broiler chickens at finisher phase

Parameter (mg/dl)	Treatments				
	T1	T2	T3	T4	SEM
Total Cholesterol	153.53[a]	148.65[a]	125.42[b]	120.05[b]	8.00
Triglycerides	143.63[a]	142.15[a]	130.05[b]	128.65[b]	7.50
Low density lipoprotein	72.51[a]	70.38[a]	58.50[b]	49.50[c]	5.50
High density lipoprotein	38.75[b]	40.42[b]	67.50[a]	68.40[a]	5.00
Very low density lipoprotein	90.55[a]	90.00[a]	86.40[b]	70.45[c]	6.50

abcd: Means with different superscript are significantly different ($p<0.05$).SEM: Standard Error of Mean.

(Source: Alabi et al., 2021)

4.5 Effects of Feeding Biodegraded Agro Industrial By-products on Nutrient Digestibility by Chicken

Nutrient digestibility and utilization are critical components in the growth and health of animals because these factors significantly influence their performance, feed conversion efficiency, and overall productivity. Besides, it refers to the ability of animals to break down and absorb nutrients from their feed. This is influenced by several factors. Maximizing nutrient digestibility and utilization in animal production is essential for achieving optimal growth, feed efficiency, and meat quality. By focusing on factors such as feed composition, enzyme supplementation, and gut health, farmers can enhance nutrient absorption, improve performance, and reduce feed costs.

Lawal *et al.* (2008; 2010; 2011; 2012 and 2013) also investigated the effects of feeding the degraded and the undegraded AIBs on the digestibility of the nutrients. There were overwhelming results that show that animals that were fed degraded AIBs have better nutrients digestibility and utilization.

Table 21: Apparent nutrient digestibility of broiler finisher fed diets containing undegraded and degraded groundnut pod

Parameters	UGNP	GNP+ Tv	GNP +An	GNP+ Rs	GNP +Mm	GNP+ RG2G	SEM	p- val
Dry matter	78.81b	81.86'	81.35'	80.46'	78.96b	78.91b	1.44	0.002
Crude protein	79.14'	83.71'	83.71'	82.81'	80.22'	79.62'	1.81	0.001
Crude fibre	52.45'	45.32'	55.67b'	57.22'	56.25b	55.91b	0.78	0.001
Ash	23.82'	26.82'	25.78'	25.14b	24.25'	24.70'	0.95	0.003
Ether extract	68.92'	81.82'	80.92'	79.11b	79.85b	62.25'	0.66	0.000
Nitrogen free	75.65'	76.27b	78.56'	77.22'	76.29b	78.96'	1.45	0.000
Neutral Detergent fibre	54.99'	61.82b	65.79'	57.21'	59.92b	56.89'	1.88	0.000
Acid Detergent Lignin.	5071'	55.65'	62.71b	68.02'	53.86'	56.65'	0.89	0.000
Acid Detergent Lignin	38.82b	39.00'	39.22'	39.54'	38.45b	38.98'	2.25	0.000
Hemicelluloses	57.23'	67.57b	67.85'	68.21'	69.93'	67.59b	0.74	0.001
Cellulose	61.37'	65.58'	64.34b	63.85'	63.91'	64.32b	0.64	0.002

Means with different superscripts along the same *rc,w* are significantly different (p<0.05); An= *Aspergillus niger,*

Tv = *Trichoderma viride,* Rs= *Rhizopus stolonffer,* Mm= *Mucor rnucedo,* RG2G = Roxazyme G2G

Table 22: Nutrient digestibility of experimental broilers (finisher phase)

Composition (%)	Control	7% UBDG	3% DBDG	5% DBDG	7% DBDG	SEM
Crude protein	73.93^{c}	71.76^{d}	75.50^{c}	77.56^{b}	79.73^{a}	2.99
Ether extract	53.82^{c}	50.42^{d}	57.85^{b}	59.05^{a}	62.54^{a}	2.45
Crude fibre	50.54^{d}	49.72^{c}	52.99^{c}	55.95^{b}	57.32^{a}	2.11
Ash	46.10^{d}	45.46^{d}	48.01^{c}	49.61^{b}	51.02^{a}	1.44
Dry matter	75.05^{c}	74.16^{c}	76.60^{c}	77.44^{b}	80.04^{a}	1.58

a, b, c, Means in the same row with different superscripts differ significantly (P<0.05);

UBDG=Undegraded brewer dried grains; DBDG=degraded brewer dried grains

Table 23: Nutrient digestibility of layers fed undegraded and degraded brewer dried grains

Composition (%)	T1 Control	T2 3%DBG	T3 5%DBG	T4 7%DBG	T5 3%UBDG	T6 5%UBDG	T7 7%UBDG	SEM
Dry matter	74.34	74.23	74.77	74.82	74.31	74.86	75.05	1.02
Fat	35.27^{b}	65.03^{a}	65.58^{a}	65.17^{a}	62.16^{c}	62.72^{c}	61.22^{c}	1.23
Crude protein	71.82^{c}	72.41^{b}	73.06^{b}	75.28^{a}	72.04^{b}	71.74^{b}	70.36^{c}	0.59
Crude fibre	58.08^{d}	61.02^{c}	63.18^{b}	65.22^{a}	58.58^{d}	57.36^{d}	55.22^{e}	1.11
Ash	58.38^{b}	59.44^{b}	59.61^{b}	62.82^{a}	57.68^{c}	57.63^{c}	56.89^{c}	1.85

a, b, c, Means in the same row with different superscripts differ significantly (p<0.05); UBDG=undegraded brewer dried grains; DBDG=degraded brewer dried grains; SEM= Standard Error of Mean

Table 24: Dry matter, crude protein, ash and NFE digestibility and ether extract retention of layers fed with undegraded and degraded citrus pulp

Composition (%)	Control	3% DCTP	5% DCTP	7% DCTP	3% UCTP	5% UCTP	7% UCTP	SEM
Dry matter	87.21^{a}	82.38^{c}	84.71^{b}	84.28^{b}	79.57^{cd}	76.16^{d}	76.24^{d}	1.20
Ether Extract	8.80	8.67	8.73	8.74	8.62	8.67	8.61	0.04
Crude Fibre	48.22^{b}	50.14^{a}	51.82^{a}	51.21^{a}	46.45^{c}	46.27^{c}	45.75^{c}	0.50
Ash	44.21^{a}	41.16^{b}	42.24^{ab}	44.56^{a}	42.71^{ab}	41.38^{b}	40.00^{b}	0.22
NFE	14.02^{c}	17.79^{b}	18.51^{b}	20.23^{a}	18.21^{b}	20.16^{a}	18.12^{b}	0.22

Means with different superscripts along the same row are significantly (p<0.05) different.

DCP=degraded citrus pulp and UCP=undegraded citrus pulp

4.6 Effects of Feeding Biodegraded Agro Industrial By-products on Viscosity in Gastro Intestinal Tract

Viscosity in the gastrointestinal tract (GIT) of broilers is closely linked to the presence of certain types of fiber in their feed. High viscosity in the gut can impair nutrient digestion and absorption, leading to poorer growth performance and feed conversion efficiency in animals (Jha and Mishra 2021; Singh and Kim 2021). There is insoluble fiber and it is found in ingredients like corn, rice, and some types of bran. This fiber does not dissolve in water and does not significantly affect gut viscosity. It mostly adds bulk to the feed and helps with gut motility. There is also the soluble fiber which is often found in ingredients like barley, rye, wheat, and oats, dissolves in water and forms a gel-like substance. Hence, AIBs from the above food may likely have the soluble fibre too. It is the primary contributor to increased viscosity in the GIT. Examples include β-glucans and arabinoxylans. High viscosity in the GIT of monogastrics due to soluble fibers in the feed can lead to decreased nutrient digestibility, impaired feed efficiency, and potential health issues. Use of enzyme and careful feed formulation are key strategies to manage gut viscosity and ensure optimal growth and performance. Balancing soluble and insoluble fibers in the diet is crucial for maintaining healthy digestive function and nutrient utilization (Lin and Olukosi, 2021).

Table 25: Viscosities of digesta (mPa.s) in broiler finishers on experimental diets

Parameters	Control	GNP+An	GNP+Tv	GNP+Rs	GNP+Mm	GNP+RG2G	SEM	p-Value
Crop	4.30'	3.5Q^{b}	3.44^{b}	3.66^{b}	3.86^{b}	4.00'	0.012	0.0004
Gizzard	3.00'	2.35^{b}	2.11'	2.51^{b}	2.77$^{'b}$	2.81'	0.031	0.0021
Large intestine	2.02'	1.96'	1.86^{b}	1.92'	1.95'	2.00'	0.022	0.0001
Small intestine	2.55'	1.54^{b}	1.53^{b}	1.54^{b}	1.55^{b}	2.30'	0.015	0.0001

Means with different superscripts along the same *rc,w* are significantly different (p<0.05),
An= *Aspergillus niger,* Tv = *Trichoderma viride,* Rs= *Rhizopus stolonffer,*
Mm= *Mucor rnucedo,* RG2G = Roxazyme G2G

4.7 EFFECTS ON LAYERS

With my co-workers, we were also interested in the effects of biodegradation of AIBs on the quality of egg production. Lawal *et al*. (2016); worked on performance and egg quality by laying birds fed *Penicillium chrysogenum* degraded brewer dried grains. It was reported that *Penicillium chrysogenum* degraded brewer`s dried grains (BDG) had positive effect on egg quality of layers in this work, and this impacted well on the egg quality characteristics of layers.

Table 26: Performance characteristics of experimental layers fed undegraded and degraded brewer dried grains

Composition	T1 (0% BDG)	T2 (3% DBDG)	T3 (5% DBDG)	T4 (7% DBDG)	T5 (3% UBDG)	T6 (5% UBDG)	T7 (7% UBDG)	SEM
Feed intake (g/b/d)	141.97^{b}	152.72^{b}	170.99^{a}	173.94^{a}	132.51^{c}	131.64^{c}	131.70^{c}	3.51
Weight gain (g/b/d)	50.88^{c}	65.54^{b}	67.72^{a}	68.43^{a}	46.65^{d}	46.35^{d}	45.87^{d}	2.01
FCR	2.79^{b}	2.33^{c}	2.20^{c}	2.11^{d}	2.84^{a}	2.84^{a}	2.91^{a}	0.09
Hen-day production (%)	67.93^{b}	68.41^{b}	70.36^{a}	71.22^{a}	64.34^{c}	64.11^{c}	61.52^{d}	1.34
Mortality	0	0	1	0	1	0	0	0.00
Relative cost benefit (%)	0.00	3.74	4.19	4.23	3.66	3.66	3.42	-----

a, b, c, Means in the same row with different superscripts differ significantly (P<0.05); UBDG=undegraded brewer dried grains; DBDG=degraded brewer dried grains.
FCR=Feed conversion ratio; SEM= Standard Error of Mean

Table 27: Performance characteristics of the birds fed with undegraded and degraded citrus pulp

Parameters	Control	3% DCTP	5% DCTP	7% DCTP	3% UCTP	5% UCTP	7% UCTP	SEM
Egg Production (%)	88.00[a]	87.00[a]	87.00[ab]	89.00[a]	87.00[ab]	85.00[b]	84.00[b]	2.03
Feed intake (kg/bird/week)	4.65[ab]	4.63[ab]	4.72[ab]	4.80[a]	4.61[b]	4.50[b]	4.41[c]	0.04
Feed intake (kg/bird/day)	0.66	0.66	0.66	0.69	0.69	0.67	0.69	0.005
Body wt (kg/ bird/week)	1.97	1.99	1.99	1.97	1.97	1.99	2.04	0.014
Mortality	0	0	0	0	0	0	0	0.00
Feed Conversion Ratio	2.60	2.33	2.32	2.46	2.40	2.37	2.37	

Means with different superscripts along the same row are significantly (P<0.05) different.
DCTP=degraded citrus pulp and UCTP=undegraded citrus pulp

Lawal *et al*. (2012) observed that there were significant (p<0.05) differences in weights of eggs, weights of yolk and albumen and shell thickness. Increase in weights of eggs obtained from birds fed degraded AIB may be as a result of better availability, digestibility and utilization of nutrients by the birds. Shells obtained from eggs placed on degraded citrus pulp were thicker. This shows better availability of minerals like calcium and phosphorus. In the work of Lawal (2007), it was reported that *A. niger* has the ability to release the enzyme phytase and this enzyme hydrolyses phytate thereby releasing the bound minerals.

Table 28: Egg quality parameters

Composition (%)	Control	3% DCP	5% DCP	7% DCP	3% UCP	5% UCP	7% UCP	SEM
Weight of Egg (g)	51.42[ab]	50.48[b]	50.80[b]	52.61[a]	49.91[ab]	47.63[c]	47.20[c]	3.10
Yolk Length (cm)	4.50	4.50	4.51	4.55	4.22	3.81	3.80	0.49
Wt. of Yolk and Albumen (g)	49.47[a]	48.60[ab]	48.81[ab]	50.61[a]	48.06[ab]	45.68[b]	45.32[b]	2.65
Wt. of Yolk (g)	32.70	32.00	32.11	33.72	31.75	30.17	30.11	1.73
Wt. of Albumen (g)	16.77	16.60	16.70	16.89	16.31	15.51	15.21	4.58
Shell thickness (mm)	0.34[a]	0.31[ab]	0.33[a]	0.35[a]	0.31[ab]	0.3[ab]	0.27[c]	0.01
Albumen Percentage (%)	67.37	67.12	67.13	67.90	67.32	67.43	67.78	2.45
Yolk Percentage (%)	36.41	36.61	36.80	35.91	36.38	36.65	36.21	2.12

Means with different superscripts along the same row are significantly (P<0.05) different.
DCTP=degraded citrus pulp and UCTP=undegraded citrus pulp

Table 29: Egg quality characteristics of layers fed undegraded and degraded brewer dried grains

Composition (%)	T1 Control	T2 3%DBG	T3 5%DBG	T4 7%DBG	T5 3%UBDG	T6 5%UBDG	T7 7%UBDG	SEM
Egg weight (g)	66.67^{ab}	67.67^{a}	67.98^{a}	68.45^{a}	65.87^{b}	62.38^{c}	63.44^{c}	1.22
Shell thickness (mm)	0.35^{b}	0.37^{a}	0.37^{a}	0.38^{a}	0.33^{c}	0.32^{c}	0.33^{c}	0.002
Yolk colour	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Yolk height (cm)	1.40	1.55	1.55	1.56	1.40	1.39	1.39	0.02
Shell weight (g)	5.64	5.64	5.65	5.65	5.64	5.64	5.63	0.05
Yolk diameter (cm)	3.78	4.18	4.07	4.00	3.88	4.08	4.08	0.02
Yolk index	0.37	0.37	0.38	0.39	0.36	0.34	0.34	0.04

a, b, c, Means in the same row with different superscripts differ significantly (p<0.05); UBDG=undegraded brewer dried grains; DBDG=degraded brewer dried grains; SEM= Standard Error of Mean.

In another work carried out by Ayoola et al 2024, on effects of Housing and Feeding Types on Growth and Physiological Performance of Growing Rabbits (*Oryctolagus cuniculus*) in Humid Tropics, findings indicated that the three housing systems could be used effectively for rabbit production. Besides, the battery cage system had the highest average body weight gain and FCR. However, the concrete pen with the soil filled floor system may be considered a suitable alternative housing systems because it satisfies the specific requirement of rabbits and also allays the ethical concern related to animal welfare in modern livestock production. Feeding forages only to growing rabbits or concentrate only as their main diet should be done cautiously due to disrupting the gastrointestinal tracts. On the other hand, a feeding system of concentrate or a combination of forage and concentrate yielded good results.

4.8 MY ROMANCE WITH DAIRY SCIENCE

Mr. Vice-Chancellor Sir, my focus shifted from monogastrics to ruminants (most especially dairy animals) and I began to work on this area steadily and rapidly as I remember Obasanjo Farms in my home town (Ayetoro, Ogun State) in the 1980s. There used to be a dairy farm where we had a bull nicknamed Oba and the female, cow, nicknamed Sanjo. They were both exotic as they were imported into the country. Painfully, within a short time of their arrival in Nigeria, Oba died and Sanjo also died. They were exotic. I think they came from Netherland. As a young lad, I was curious about what led to their demise. I thought about it several times but I could not provide any answers. But, today, I can conveniently provide answers as a trained Animal Scientist who has unabated and undying interest in dairy farming. My interest in dairy farming is beyond academic pugilism, I spend time with cattle, I know them and they know me. I now know why and what killed Oba and Sanjo. Mr. Vice Chancellor, Sir, now I know why a Fulani man will cry like a baby when he loses any cow, bull, heifer or calf. Nobody can understand if you are not close to the cattle. They are peculiar animals. In fact, in India, they are gods! Indians worship them. Permit me to use this medium to discourage governments, at Federal, State or Local levels to stop importing exotic cattle into our country rather they should embrace the use of Artificial Insemination. Artificial Insemination is the way out! I cannot thank Bowen University enough for providing this opportunity for me to be trained in dairy farming having sent me to places for training. Majority of Nigeria's cattle are found in Northern Nigeria, primarily in Kaduna and Kano States, where the country is reported to have the sixth-largest herd of cattle in Africa (Csiro, 2020). White Fulani (Bunaji) and Sokoto Gudali (Bokolo) cattle are the major two indigenous breeds in Nigeria which are utilized to produce milk and managed by pastoralists who barely have knowledge on the economic strength of the industry along the value chain. Currently, the nation is home to about 20 million cattle which are raised in a nomadic approach, 88.5% being used in the production of meat and the remaining is used to produce milk which is extremely low (Asoko Insight, 2020; Nathalie, 2019). Perhaps the most significant importer of dairy commodities in Africa is Nigeria. According to records, up to 98% of every dairy product consumed in the country is imported and the country spends US$1.3 billion on such importation on average every year (Business Day, 2019). The persistent inadequacy in the governance and regulatory institutions can be used to explain dairy multinational companies' (MNCs) predilection for imported factor inputs., as well as the increasing costs of doing business in Nigeria (The Economist, 2015). Dairy products provide the most important amino acid required for body building as well as tissues repairs in human beings (FCW, 2016) and dairy production leads to increased milk sales and income for farmers. Most of the raw milk produced in Nigeria is traded or processed informally by Fulani women into local products. Only a small percentage estimated at 5% is purchased by a few formal processors. A number of government schemes meant to boost local dairy value chain development and make the country self-sufficient in milk production had few results. The current effort to establish cattle colonies in different regions of the country to suppress herdsmen insurgence and boost milk production, for instance, was confronted with significant community resistance (Akinnaso, 2018). Instead, the dairy business remains dominated by a few dairy MNCs, which though incorporated as manufacturing outfits, are more likely to employ strategies that allow them import finished and semi-finished dairy products through their worldwide value chains. While this technique definitely promotes the business goals of the MNCs, local dairy production remains undermined. However, the dairy industry in many countries operates through informal markets with milk being sold by the roadside, in raw form, and/or with low quality standards. In the business of dairy farming and processing, the Nigerian segment is predicted the most fragmented. Up to 95% of all locally produced milk in the country come from smallholder farmers, with little progress made in the areas of cooperative formation, commercial dairy farming and milk production. Sabo Nanono (2021) stated that the country's urbanization and expanding population in Nigeria were to be blamed for the growing gap between the demand for and supply of dairy products and as the population continues to increase, milk has become increasingly in demand, especially for the residents in urban areas. The formal Nigerian dairy market is primarily controlled by multinationals owned by European dairy cooperatives such as Friesland Campina WAMCO (FCW) and Arla, and corporations such as PZ Wilmar (Nutricima), Fan Milk, Promasidor and CHI, who rely on milk imports as raw materials. Incidentally, these foreign corporations are importing and marketing processed dairy goods, or at best importing milk powder and reconstituting it into liquid milk and other dairy items such as yoghurt, ice cream and confectioneries (Ilu *et al.*, 2016). Friesland Campina WAMCO (FCW) is arguably the largest importer of dairy products in Africa, controlling about 75% of the entire dairy market in Nigeria and sourcing raw milk locally (Nathalie, 2019). FCW initiated Dairy Development Programme (DDP) programme in Nigeria in August 2010 as the first practical attempt at mainstreaming smallholder cattle farmers into the national dairy value chain (FrieslandCampina, 2019).

Figure 20: A Girolando breed of cow

Figure 21: Another picture of Girolando breed of cow

Figure 22: A breed of Holstein Friesen cow

At Bowen dairy Unit, Olagbaju (2024) reported on the Efficacy of Vaginal Electrical Resistance (VER) Measurement in ruminant animals Synchronized using Ovsynch and Double PG Protocol. This research was carried out through grant received from the University and I was privileged to be the Principal Investigator. The study was aimed at evaluating the efficacy of VER measurement in animals synchronized using the Ovsynch and Double PG protocols. This work became necessary because one of the major constraints to good reproductive performance of the ruminant animals is low estrus detection. Addressing this reproductive challenge is critical for improving the productivity and economic viability of ruminant animal farming. It is therefore essential to

explore innovative methods to enhance reproductive efficiency in our animals. One promising technique is the measurement of electrical resistance of vaginal mucus (ERVM) during estrus to determine the optimal timing for artificial insemination (AI). Accurate estrus detection is crucial for improving reproductive performance, yet it remains a significant constraint due to environmental and physiological factors (Arakawa, 2020). Techniques such as vaginal electrical resistance (VER) measurement offer a non-invasive method to detect estrus by monitoring changes in the electrical conductivity of vaginal mucus, which correspond to various stages of the oestrous cycle (O'Connor, 2007).
VER measurement has shown promise in several species not only in cattle but also in buffalo, camels, and sheep for detecting estrus and timing insemination (Purohit *et al*., 2020; Talukder *et al*., 2018). Recent studies have demonstrated that cyclic changes in vaginal impedance are closely related to estrus behaviour in animals (Murtaza *et al*., 2020). By investigating the relationship between VER patterns and key reproductive events, such as estrus onset and ovulation, we seek to provide valuable insights that can enhance reproductive efficiency and success rates in our animal breeding programs. In this work, thirty-six (36) animals were randomly divided into two synchronization protocols and a control; Group 1 was the control without hormonal treatment Group 2, was administered with double prostaglandin, and Group 3 Ovsynch protocols. The results revealed that the ones in the control group (Group 1) showed an unpredictable pattern in the onset of estrus. The mean VER values of treatment groups are within the normal range. The onset of estrus correlated with the lowest VER reading post-treatment, observed 24 to 36 hours in 40% of animals in both groups. Blood progesterone and estradiol revealed distinct but synchronized patterns in both groups. Group 2 displayed a consistent decline in blood progesterone from day 0 to 7, and a spike on days 7-11, attributed to the second prostaglandin analogue administration. The subsequent decline on days 12-13 signaled impending estrus, accompanied by a rise in blood estradiol. Group 3 exhibited a progesterone spike on day 10, with a corresponding decrease in estradiol. The study demonstrates that regardless of synchronization protocol, the lowest mean VER reading post-treatment corresponds to

high blood estradiol and low progesterone concentrations. This consistent pattern highlights the reliability of VER measurements in predicting estrus, while no significant difference in VER means the two protocols offer flexibility to ruminant animal farmers in choosing synchronization methods based on specific breeding objectives.

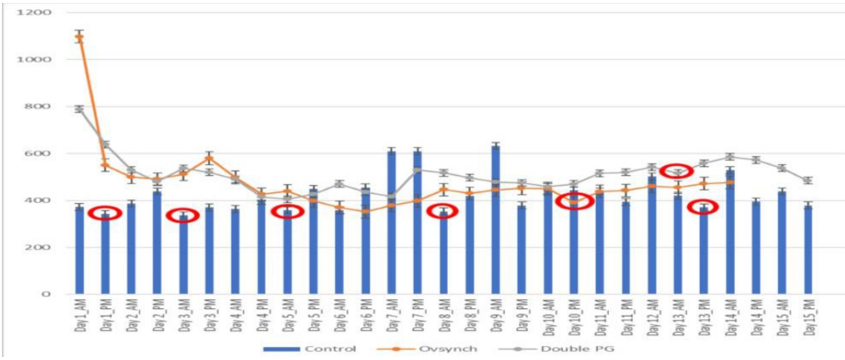

Figure 23: Mean vaginal resistance reading for animals in the control and experimental group. The red rings signify the onset of estrus (standing heat) in the animals. Animals in the control group (n=12) was observed to come on heat at different intervals

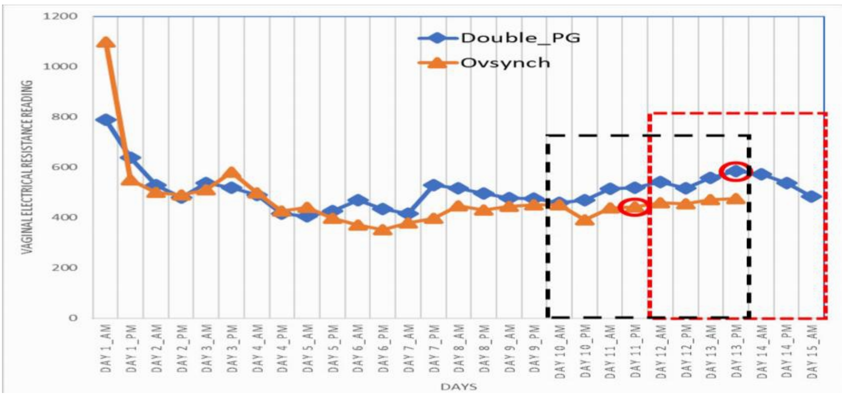

Figure 24: Average vaginal electrical resistance reading for the animals in groups 2 and 3. The orange and blue arrows indicate the last hormonal treatment. The red and black dotted boxes show the duration of the estrus periods post the last hormonal treatment. The chart shows that at the beginning of the experiment, the animals were at different stages of the oestrous cycle. The VER post hormonal treatment chart is however indicated in the dotted box (red for group 2 and black for group 3). The red rings indicate the likely time of ovulation after the completion of the hormonal treatment.

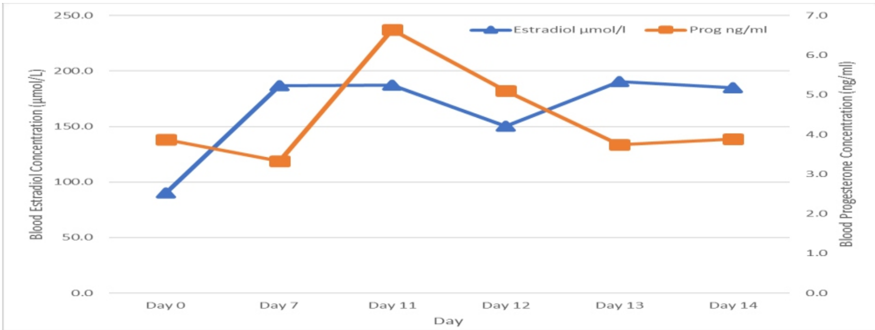

Figure 25: Hormonal profile of animals subject to the double dose of prostaglandin (group 2).

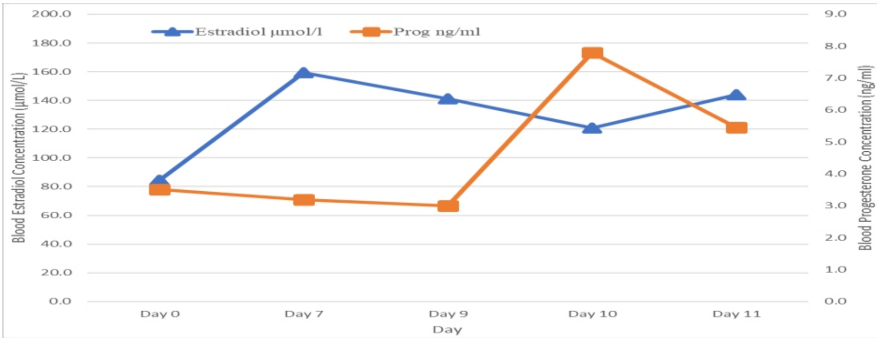

Figure 26: The hormonal profile of WAD does subject to the Ovsynch protocol (group 3).

Findings from this study underscore the importance of VER measurements and hormonal profiling in predicting estrus onset and optimizing reproductive management in ruminant animals. By elucidating the relationships between these physiological indicators and synchronization protocols, this research contributes to the advancement of cattle reproductive science. Implementing these findings in practice could lead to improved breeding efficiency and profitability in cattle, sheep and goats production in Nigeria and sub-Saharan Africa.

Lawal *et al*. (2012) investigated the observable changes in the nutritional quality of corn offal fermented with *Penicillium notatum* and *Penicillium citrinum* for cattle feed production. The aim of this study was to evaluate changes in nutritional quality of corn offal (CO) fermented with *Penicillium notatum* and *Penicillium citrinum* using *invitro* gas production technique. After the fungal biodegradation of CO in a solid state fermentation, the chemical composition and *in vitro* digestibility of the undegraded and the degraded CO were determined. The value of organic matter digestibility (OMD) was from 28.46% to 62.28%, metabolizable energy (ME) improved from 4.59 to 10.18MJ/kg DM and short chain fatty acid (SCFA) values ranged from 0.03 to 0.85µ M. There were significant ($P<0.05$) differences in the values obtained for potentially degradable fractions (b). Rate of degradation of b, that is, C, was faster in the degraded CO compared with the undegraded CO. The obtained results revealed the possibility of using fungal treatment for the improvement of nutritional quality of fibrous materials for cattle nutrition. The significant increase in the CP after fungal biodegradation of CO can be traced to the fungal growth, which increased the hydrolysis of starch to glucose and its subsequent use by same organisms as a carbon source to synthesize fungal biomass rich in protein (Bernal-Barragán *et al.*, 2022). Besides, fungi have the ability to produce a variety of enzymes. These enzymes help to degrade the non-starch polysaccharides (NSPs) in the substrates. The produced enzymes break the cell walls of the fibrous materials and thereby reduce the crude and the detergent fibres. Liang et al., (2024) opined that lignifications of structural polysaccharides not only inhibit ruminal microbial digestion of polysaccharides by forming 3-D matrix, but also that the presence of highly lignified tissues forms a physical barrier preventing accessibility of the otherwise highly digestible tissue to the action of hydrolytic enzymes of the rumen micro-organisms. Fungal biodegradation of corn offal therefore has the potential of breaking the structural carbohydrates and thereby increase its digestibility by the ruminant animals. There were significant ($p<0.05$) differences in the values for *Penicillium notatum corn offal* (PNC), *Penicillium citrinum corn offal* (PCC) and undegraded corn offal (UCO). The highest value for OMD (50.53%) was obtained in corn offal degraded with *Penicillium* *citrinum* followed by the value obtained for *Penicillium notatum* degraded corn offal (46.56%). The higher OMD obtained from fungal degraded CO suggests that the microorganisms in the animals can possibly increase the nutrient availability. The Metabolizable energy values were 7.97, 8.08 and 6.76 MJ/Kg DM for PNC, PCC and UCO respectively. According to Gilbert and Hazelwood (1993), fungal biodegradation can increase the ME of agro industrial by products as it leads to an increase in the digestibility of cell wall components and this also enhances the starch digestibility. Breakdown of β-glucan via fungi can result in more efficient starch utilization and hence increase metabolizable energy. The *in vitro* gas production method had been employed by many workers to determine the energy value of feeds According to Wu *et al.* (2023), *in vitro* gas production technique may be considered for estimating ME in tropical feedstuffs; it is not laborious and less costly. SCFA was highest in *Penicillium citrinum* degraded corn offal (0.52 μmol) and least in the undegraded corn offal (0.23μmol). According to Lobos *et al*. (2024), SCFA indicates the energy available to the animals; it contributes up to 80% of animal daily energy requirements. The higher SCFA in the treated substrates might be due to increase in the crude protein and reduction in the crude fibre. SCFA indicates the energy available to the animal. Methane was significantly reduced in the fungi degraded corn offal, (Figure 1). Methane gas is an important gas among gases produced by ruminants at fermentation and it has been reported to be an energy loss to the animals and when emitted, it contributes to the destruction of ozone layer. Besides, when the dry matter degradation occurs in rumen by the action of microorganisms, there is production of gas which mainly constitutes hydrogen, carbon dioxide and methane. When it accumulates in the rumen, it results in bloat (Tugay et al., 2018; Guadayo et al., 2019; Adiprasito and Patáková, 2024).

Table 30: Chemical composition (g/100gDM) of *Penicillium notatum* and *Penicillium citrinum* degraded corn offal and undegraded corn offal

Parameters	PNC	PCC	UCO	SEM
Dry matter	93.18	93.34	93.10	0.11
Ash	5.00^{a}	5.50^{b}	4.00^{b}	0.34
Crude fiber	5.41^{c}	6.22^{b}	8.02^{a}	0.01
Crude protein	14.41^{b}	16.22^{a}	10.69^{c}	0.17
Acid detergent fiber	33.92^{b}	32.12^{c}	35.00^{a}	0.12
Acid detergent lignin	3.64^{c}	4.13^{b}	5.00^{a}	0.06
Neutral detergent fiber	40.00^{b}	40.50^{b}	52.50^{a}	0.08
Cellulose	31.53^{b}	31.46^{b}	36.11^{a}	0.02
Hemicellulose	18.78^{b}	18.36^{b}	20.74^{a}	0.02

a,b,c, means on the same column with different superscripts are significantly varied ($p < 0.05$)
PNC = Penicillium notatum degraded corn offal, PCC = Penicillium citrinum degraded corn offal, UCO=Control; it is the undegraded CO. SEM= standard error of the mean

Table 31: Organic matter digestibility (%), short chain fatty acid (µmol) and metabolizable energy (MJ/Kg DM) of degraded and undegraded corn offal

Parameters	PNC	PCC	UCO	SEM
Short chain fatty acid (µmol)	0.32^{b}	0.52^{a}	0.23^{c}	0.03
Organic matter digestibility (%)	50.56^{a}	46.56^{b}	39.79^{c}	0.15
Metabolizable energy (MJ/Kg DM)	7.97^{a}	8.08^{a}	6.76^{b}	0.19

a,b,c, means on the same column with different superscripts are significantly varied ($P < 0.05$)
PNC = Penicillium notatum degraded corn offal, PCC = Penicillium citrinum degraded corn offal, UCO=Control; it is the undegraded CO. SEM= standard error of the mean

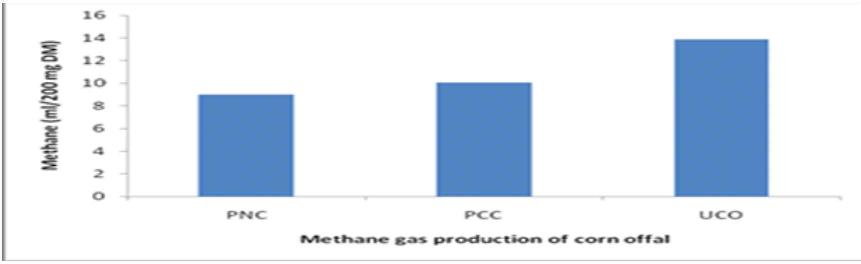

Figure 27: Methane (mL/200mgDM) production from corn offal

Table 32: *In vitro* gas production characteristics of degraded and undegraded corn offal

Parameters	PNC	PCC	UCO	SEM
A	1.44	2.03	2.22	0.24
A + B	23.83	34.66	37.33	1.00
B	22.39	32.63	35.11	1.37
C(h^{-1})	0.16	0.17	0.14	0.02
T	9.67	9.25	7.78	0.42
Y	6.27	9.66	8.33	1.01

a, b, means on the same column with different superscripts are significantly varied ($p< 0.05$),
PNC = *Penicillium notatum* degraded corn offal, PCC = Penicillium citrinum degraded corn offal,
UCO=Control; it is the undegraded CO. SEM= standard error of the mean,
(a+b)= Potential extent of degradation, b= fermentation of the insoluble but degradable fraction,
y= volume of gas produced, c= Rates of gas production

During the Dairy Conference that we had in 2022 (co-sponsored by Friesland Campina WAMCO), another work was carried out in Agriculture Programme that concentrated on evaluation of Bowen Milk Collection Centre, Iwo, Osun State with the Sub Theme: Dairy Production and Sustainable Development Goal. Afolabi *et al.* (2023) reported that Milk Collection Centres were established to promote domestic milk production and lessen Nigeria's reliance on the importation of milk and other related dairy products. The aim is to promote milk production in the country by obtaining milk from farmers with local and exotic breeds alike. As the Nigerian population continues to increase, milk has become increasingly in demand, especially for those resident in urban areas. Restricted numbers of Milk Collection Centres in Nigeria make milk supply difficult for the dairy farmers which are not located close to them. Despite the fact that milk collection centres were developed to encourage the production of milk locally and aid reduction of Nigeria's dependence on the importation of milk and other related dairy products, they were never fully popularized due to poor funding and management. Thus, leading to heavy reliance on the importation of powdered milk. Seven (7) Fulani settlements were purposively selected from Iwo town and its environs based on fact that they are the major milk suppliers of Bowen Milk Collection Centre. Thereafter, 60 farmers were randomly sampled from the settlements. Scheduled Interview was used to collect data on respondents' socioeconomic characteristics, attitude of dairy farmers towards Bowen MCC, constraints faced by dairy farmers in milk supply, characteristics of Bowen MCC and challenges encountered by Bowen MCC. Result shows that majority of respondents were males (85.0%), married (98.3%) with mean age of 40±7.63 years and household size of 9±1.93 persons. All (100%) respondents engaged in farming (100.0%) as primary occupation with mean monthly income of ₦35,782.18±9,036.04 ($80.83) and mean years of experience of 31.00±7.19 years. More than half (52.1%) of the respondents had positive attitude towards the use of MCC and more (63.3%) of the respondents had high level of constraints in the supply of raw milk to the MCC with unimproved genetic composition of local breeds for milk production leading to low yield (

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The use of biodegraded agro-industrial byproducts in animal feeding presents a sustainable and economically viable solution for the livestock industry. These byproducts, which are often abundant and underutilized, can be transformed through biodegradation processes to enhance their nutritional value and digestibility. Biodegradation, facilitated by microorganisms or enzymatic treatments, can reduce anti-nutritional factors, improve fiber breakdown, and enhance the bioavailability of nutrients. This can lead to improved animal health, productivity, and lower feed costs. Additionally, using agro-industrial byproducts as animal feed helps mitigate environmental issues by reducing waste and promoting a circular economy. However, careful assessment of the nutritional content, possible contaminants, and consistency in biodegradation processes is essential to ensure safe and effective usage.

5.2 Recommendations

1. **Research and Development**: continued research on optimizing biodegradation processes for various agro-industrial byproducts is necessary to improve the safety, efficiency, and scalability of their use in animal feeding.
2. **Nutritional Evaluation**: each byproduct should undergo thorough analysis to ensure it meets the nutritional needs of specific animal species and stages of production, preventing deficiencies or toxicities.
3. **Regulatory Guidelines**: governments and agricultural bodies should develop guidelines to regulate the inclusion levels, processing standards, and safety of biodegraded byproducts used in animal feeds to protect animal health and food safety.
4. **Collaboration with Agro-Industries**: partnerships between agro-industrial companies and livestock producers should be encouraged to facilitate the sourcing of byproducts and ensure consistent supply chains.
5. **Farmer Training**: educating farmers on the proper use, handling, and storage of biodegraded byproducts in animal feeding will maximize their benefits and minimize risks.
6. **Environmental Monitoring**: continuous monitoring of the environmental impact of using biodegraded byproducts in animal feeding should be conducted to ensure sustainability and minimize any potential negative effects on ecosystems. These steps will help enhance the utilization of biodegraded agro-industrial byproducts in a way that is safe, sustainable, and beneficial for both the livestock industry and the environment.
7. **Government agencies, financial institutions, and agricultural development organizations** should develop and implement accessible credit schemes and financial support programs specifically designed for dairy farmers. They should provide grants or low-interest loans to assist with infrastructure investments and operational costs, thereby alleviating financial constraints faced by the farmers.
8. **Agricultural extension services, dairy cooperatives, and**

industry associations should enhance support services by organizing regular training sessions and workshops on hygienic milking practices and milk handling. They should offer technical support and resources to help farmers adhere to best practices, improve milk quality, and manage disease outbreaks effectively.

9. **Government bodies, local authorities, and private sector stakeholders** should invest in infrastructure improvements, including better grazing land and transportation facilities. They should facilitate partnerships between the public and private sectors to address logistical challenges and improve the overall efficiency of the milk delivery process.

10. **Cooling plant operators and dairy cooperatives** should work to increase accessibility and engagement by improving communication channels with farmers. They should extend operational hours and enhance milk collection services to better meet farmers' needs and actively engage with farmers to address their concerns and feedback.

By taking these actions, stakeholders can effectively address the constraints identified in the analysis, enhance the benefits of milk delivery to cooling plants, and ultimately improve the profitability and satisfaction of dairy farmers. This holistic approach will strengthen the dairy sector's sustainability and growth while ensuring that farmers are better supported in their operations.

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Bowen University

"When the Lord turned again the captivity of Zion, we were like them that dream."

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