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ENERGY FOR AGRICULTURE: THE MECHANISATION OPTION

BY

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INTRODUCTION

In the beginning, "God made two great lights, the grater light to rule the day and the lesser light to rule the night. He made the stars also." Genesis chapter 1 verses 15. This greater light the sun, produces energy by converting mass into energy at a rate of millions of tones per second. The total amount of energy striking the outer atmosphere of the earth is 35, 000 times the energy used annually by man. The average intensity measured on a plane perpendicular to its path on earth is 1.36 kilowatts per square meter. This number is known as the solar constant.

The sun endowed by God is thus the source of energy for agriculture and indeed for all human activities either directly or indirectly. Certainly we need to thank God for daily meals and the clothes we wear for He provides the energy needed for their production. The question of how efficient and in what form we apply the various types of energy derived from this source is the focus of this inaugural.

This inaugural is the second from the Department of Agricultural Engineering. The first one was given by Professor G.A. Makanjuola on 20th October, 1977 on "Agricultural Mechanization in Nigeria: The prospects and promises". Taking off from the point he stopped, it could have been useful to review what we had been doing since 1977 on our mechanization efforts and our achievements with all the prospects and promises of our potentials then, thus my first impulse was to title this inaugural lecture "Mechanization Nightmare in Nigeria" What would better describe our efforts since that inaugural.

The fact that we are where we are today would have made the pronouncements in this inaugural very negative and will paint a picture of hopelessness. Rather than do this, it was decided to put energy and food system in perspective with the hope that energy implications of providing adequate food, fiber and other agricultural resources for the ever-expanding Nigerian population will contribute to our future decisions and actions.

ENERGY AND EARLY DEVELOPMENT

Energy simply defined, is capacity to do work, that is, to cause a body to move by an exerted force. The rate of doing work is called power. All through istory, energy and its evolving uses have figured centrally in human civilization. The need for energy was apparent even to the primitive men who threw heffty crude stone tools to augment their own muscle power to kill wild animals. The desire to produce and manage energy is manifested further in the production and controlled use of fire; Chinese farmers building irrigation systems to improve their rice yields; domestication of animals; European coal miners burrowing ever deeper; the invention of the steam engine; Albert Einstein exploring the relationship between energy and mass with his famous equation $E = MC^2$; Huygens internal – combustion engine run on gun – powder, Watt's modern steam engine and Otto modern four stroke internal combustion engine. In all of these, energy has been the main issue. The central motivating force has ever been the desire of mankind to improve its energy efficiency. The agricultural revolutions resulting from these developments had been largely responsible for human settlements and social structures. The French economic historian, Fernard Brandel argued that major innovations in energy technologies occurred "when society came up against the ceiling of the impossible."

When population pressures could no longer be sustained under then existing energy sources. For example, the development of steam engine was spurred by the disappearing forests of Europe and the ensuing need for coal as fuel.

Figure 1 gives the daily energy consumption per capita for six stages of man's development. The primitive man's main activity was to scout for food and eat. His rate of energy consumption was 2000 kilocalories per day. The 1978 figures for food supply per capital in developed countries was 3,353kilo calories per day (129% of daily requirement). The figure for developing countries was 2,203 kilo calories per day (96% of daily requirements). The hunting man energy consumption of about 4,000 kilo calories per day must have been due to domestication of fire.

The primitive agricultural man grew crops using manual tools and animal energy. His daily energy consumption rose to about 12,000 kilo calories. The advanced agricultural man (North western Europe A.D.1400) used coal for heating, water and wind power and animal transportation. His daily energy consumptions rose to about 24, 000 kilo calories. At the height of the low – technology industrial revolution (1850 – 70%) per capita daily energy consumption reached 70,000 kilo calories in England, Germany and U.S.A.

In 1970, the technological man (e.g.U.S.A.) consumed 230, 000 kilo calories daily. This increase was due to electrical power usage and

automobile. Today the industrial regions of the world of less than 30% of the world population consume 80% of the world's energy. The implications of this on agriculture in some way is demonstrated by the data in table 1.

Table 1 **Total grain production and food gaps (excess of production to consumption projected to 1990) (t x 10 tones) Barr 1981**

	Population Distribution	Production	Gap
Developed Countries (exclusing U.S.S.R and	16%	640	+152
E. Europe			-61
China	20%	290	-10
E. Europe and U.S.S.R.	8%	370	
Developing Countries	8%	205	-24
Developing Countries (Low income)	48%	260	-47
World	100%	1765	+10

The developed countries produced over 25% grain needs. The developing countries like ours produce about 33% of our daily needs. The overall world figure shows 10% grain surplus. In fact, the problem in the U.S.A. and the EEC these days is of increasing surpluses which are economically and politically troublesome. The EEC today spends a staggering amount of resources on agricultural policy most of which goes to subsidizing animals. The problem of getting rid of the mountains of milk, butter and cheese produced had led to feeding them back to the animals. The policy is particularly worrisome when it is realised that 90% of the energy in the food is lost every time it is fed to animals.

The United states agricultural productivity is now considered to be in the science phase with an annual growth rate of 1.6% since 1945 (total farm output per unit has doubled). The period between 1920 and 1945 led to increased acreage per farm as given in Table 2. The average farm size was 210, and 405 acres in 1950 and 1979 respectively. These compares to Nigeria Farm size of about 1 to 8 acres.

Table2: **Average Farm size in the United States**

Year	Acres / Farm	Average Annual Increase
1950	210	+4.1%
1960	295	+4.1%
1970	375	+2.7%
1975	395	+1.1%
1979	405	+0.6%

Lamp (1982)

The farm population in U.S. was drastically reduced. (3.6% of total population in 1977). The agricultural production was increased by 21% while the number of hours of farm work was reduced by 22%.

Energy input into Agriculture

Agriculture is essentially an energy conversion process. It is a producer as well as a consumer of energy. The energy production process involves the conversion of solar energy into bio – mass by way of photosynthesis. The optimum level of photosynthetic efficiency of plants has been calculated to be of the order of 6 per cent. Most cereals and oil seed plants have efficiencies in the range of 0.5 – 0.2 percent.

The modern trend in agricultural production is to increase the photosynthetic efficiency through better plant and other growth promoting inputs. Thus countries with high agricultural productivities are those that use high levels of commercial energies for their agriculture.

It has been found that there is close relationship between energy inputs into agriculture, the yield and the commercial energy use and cereal output per hectare and per agricultural worker for different regions of the world.

Table 3: **Commercial Energy use Cereal Output per Hectare and per Agricultural Worker, 1972**

	Energy/ heactare	Energy/ worker	Output/ hectare	Output/ worker
	….. 10^9	Joules…	……	Kilograms
Developed countries	24.8	107.8	3100	10508
North America	20.2	555.8	3457	67882
Western Europe	27.9	82.4	3163	5772
Oceania	10.8	246.8	976	20746
Other developed countries	19.4	19.1	2631	2215
developed countries	2.2	2.2	1255	877
Africa	0.8	0.8	829	538
Latin America	4.2	8.6	1440	1856
Near East	3.8	4.4	1335	1386
Centrally planned economies	5.9	6.8	1744	1518
Asia	2.4	1.7	1815	911
Eastern Europe and the U.S.S.R	9.3	28.5	1682	4109
World	7.9	9.9	1821	1671

Source: FAO ROME, 1977.
The State of Food and Agriculture, 1976.

The energy expenditure per hectare were 20.2, 10.8 and 0.8 × 10^9 joules for North America, Oceanic countries and Africa respectively. The corresponding energy per farm work for the countries were 555.8, 246.8 and 0.8× 10^9 joules respectively. The output were 67,882, 20, 746 and 538 Kilograms respectively. The output per worker is also indicative of the standard of living that the economy can sustain. The energy input into farming in a region is thus indicative of the standard of living of such region.

The component parts of this energy is illustrated in table 4. The energy indicated for seed in this table is that required to process the seed.

Table 4: Commercial Energy Required for Maize Production by Modern and Traditional Methods with Respective Yields

	Modern (U.S.A)		Traditional (Mexico)	
	Qty/ha	Energy/ha (10^6 joules)	Qty/ha	Energy/ha (10 joules)
Inputs				
Machinery	4.2×10^9 joules	4200	173×10^6 joules	173
Fuel	206 litres	8240	-	-
Nitrogen fertilizer	125kg	10000	-	-
Phosphate fertilizer	34.7kg	586	-	-
Potassium fertilizer	67.2kg	605	-	-
Seed	20.7kg	621	10.4kg	
Irrigation	351×10^6 joules	351	-	
Insecticide	1.1kg	110	-	-
Herbicide	1.1kg	110	-	-
Drying	1239×10^6 joules.	1239	-	-
Electricity	3248x10 joules	3248	-	-
Transport	724x10 joules	724	-	-
TOTAL		30034		173
YIELD (kg/ha)	5083		950	

Source: Anderson, L.L., 1972.

From this table it is obvious that modern agriculture requires various forms of energy input. The energy in the traditional method is that required for manual labour assisted by draught animals. The components of energy for modern farming includes machinery, fuel, fertilizer, seeds, irrigation, insecticide, herbicide, agriculture produce drying electricity and transportation.

The agricultural share of commercial energy is shown in Table 5.

Table5: Estimated Total and Agricultural use of Commercial Energy. 1972/73.

	Total Use	Agricult-ural use	Percent used in agriculture	Per output consumption	Energy/ agricultural worker
	10		Joules......	....	Kilograms
Developed countries					
North America	135678	4637	3.4	183	107.8
Western Europe	76933	2141	2.8	333	555.8
Oceania	42912	2114	4.9	119	82.4
Other developed countries	2442	137	5.6	154	246.8
Developing countries	13391	246	1.8	99	19.1
Africa	19317	920	4.8	11	2.2
Latin America	1569	70	4.5	5	0.8
Near East	8147	313	3.8	28	8.6
Far East	2637	168	6.4	24	4.4
Centrally planned economies	6964	369	5.3	6	1.4
Asia	64091	2048	3.2	54	6.7
Easter Europe and the U.S.S.R.	14289	415	2.9	17	1.7
World	49802	1633	3.3	141	28.5
	219086	7605	3.5	59	9.9

Source: FAO ROME, 1977
The State of food and Agriculture, 1976.

The energy is the summation of the energy used for farm machinery, irrigation, fertilizers and pesticides. Mechanization is thus responsible for only a small part of total commercial energy use. The energy per agricultural worker in North America, Western Europe, and Africa are 555.8, 82.4 and 0.8×10^9 joules respectively. Clearly rapid increases in commercial energy inputs are needed for sufficient gains in agricultural production especially in Africa. Essentially the level of energy increase dictates the degree of modernization in agricultural production.

The transition to modern agricultural production methods varies from one region of the world to another. The variation are found to be influenced by the relative cost of land to that of labour. When land is inexpensive compared with that of labour, mechanization is introduced to increase production per worker. Conversely, where land is costly and labour is expensive, biological and chemical inputs are stressed. Highest productivity is usually achieved through a combination of mechanical, biological and chemical inputs.

Some Characteristics of energy input into Nigerian agriculture

Much of the food, feed, fibre, fuel and raw materials for industries in Nigeria are produced, transported and processed by human and animal power. Direct solar power is used for drying of the produce. Humans and animals are limited in individual energy capacities because of limitation in food intakes which can be converted into mechanical energy. Human beings can produce an average of 75 watts and this level of energy is grossly insufficient for a reasonable standard of living based on agricultural production. When man's energy capacity is supplemented by draught animals of average energy of 500 watts, the result is often a subsistence standard of living.

Apart from the low energy level in the traditional method of using the cutlass and hoe to clear and crop the land, the efficiency of the work done is also generally low. For instance land cleared by hand is usually left with many large stumps and stones. This make further mechanical operation on the land extremely difficult and many at times impossible. The low level of human energy input is responsible for the low hectage of the farmers. For instance, it will require 177 man – days (or 7 man- months) to clear one hectare of land in the forest zoned of the country (11TA, 1979). Another major concern in the Nigerian agricultural energy inputs is the age of the farmers. In a recent survey of male farmers in Ondo State (Idowu 1993) more than 75 percent of the farmers were above 65 years old. Worse still is the fact that those who were only part time farmers involved in order businesses like carpentry, tailoring, trading, masonry, plumbering, auto mechanics and so on.

Previous attempts have been made in the country to introduce machines into the agricultural systems. Hitherto, several factors have been responsible for the lack of success or limited success in the introduction of machines into agriculture. One of the problems have been how to introduce such machines because of lack of education and general lack of knowledge on mechanical gadgets. One of the attempts of introducing machines to farmers in the old Western State of Nigeria was through a scheme called "Farm Settlement Scheme". The cardinal objective of the scheme was to

demonstrate that modern farming is a viable, decent and lucrative way of earning ones living. Young farmers were involved in the scheme. They were given such training thought necessary for modern farming career before being settled on government acquired land.

Land were usually allocated to each farmer and the necessary machines were usually available to them. Unfortunately these settlers are soon as they acquired such skills leave the farm for salary earning jobs in government or private businesses where such training can be used, mainly these jobs are unrelated to agriculture. Thus, most trained settlers used the scheme as a stepping stone to other professions and this struck a fatal blow on the scheme. Also most farmers feel unsecured hanging their entire future on government whose decisions are atimes political rather than the authentic needs of the nation.

Another effort at introducing machines to farmers was through the scheme called the "Tractor Hiring Unit". In this scheme, properly cleared land are ploughed and harrowed for farmers at reduced rate. One of the main objectives of the scheme was to encourage farmers to increase their acreage thus enhancing their money earning power to such extent that they would be able to buy their own tractors, implements and equipment for land preparation and other farming practice. Factors that have limited the success of the scheme include:

(a) The pre – condition for qualification for such scheme is through clearing and stumping of the land. Farmers feel this amount of work is even more than that of ploughing and harrowing of land.

(b) The farmers usually have need for the service at the same time because of the timeliness involved in agricultural production.

(c) Scarcity of qualified tractor operators have limited the number of farmers buying their own tractors.

(d) The cost of tractors and farm machinery are too high for the peasant farmers. The cost of a tractor today is of the order of a million Naira.

Generally, this scheme imposed on the farmer the role of an observer on his own farm while somebody else (the contractor operator) is farming it for him. The services are generally not available when the farmer, his field and crops need them. The farmer thus hang his destiny on the bureaucratics of securing the service and the goodwill of the operator.

However, this scheme achieved some measure of success particularly in the rain forest zone close to the savanna zone. This perhaps is due to the fact that the vegetation in this region is not as dense as that towards the mangrove swamp zone, hence the first condition for qualifying for the scheme could be easily met.

It is interesting to note that Nigerian Government imported a total of 4, 962 tractors and other types of agricultural machinery valued at over N16 million between 1972 and 1974 yet the impact of such huge amount of money then was not felt. Several commentators on this have blamed the low impact on unsuitability of the imported machinery to our farming system. It appears that there is no control whatsoever on the type, model or make of machines imported. This in effect means that small quantities of different types of machines were imported annually. For example, in 1976, ten main companies distributed about 30 types of tractors: Ford (4 types), International Harvester (3 types), Massey Ferguson (3 types), David Brown (4 types) John Deere (5 types) Steyr (2 types) Fiat (2 types), Deutz (1 type) and Country (1 type). The total number of tractors was 1, 357 (One thousand, three hundred and fifty – seven) Makanjuola, (1979). This wide variety of machines creates a lot of problems in training of tractor mechanics and operators thereby resulting in big losses in investment and in yields. A good example to illustrate the problems created by this abounds around us today when we consider the problem of maintaining motor vehicles. An honest Peugeot mechanic will confess that he cannot handle Renault or any other brand of vehicle well. Also their parts are usually not interchangeable.

In many cases, the companies marketing these tractors have no facilities for training neither do they store enough spare parts. To date, there is no farm equipment company in the country which has created a small department for researching into the performance of their machines on the field with a view to modifying them or developing better machines.

One interesting contribution to mechanization training in developed countries is the donation of equipment and atimes, sectioned equipment to training institutions apart from contracting research projects to institutions by most of these companies in their home countries. These usually form effective teaching aids for the benefit of both the students and the staff members. It appears that most of these companies are not positively deposed to carry this out in Nigeria. Several years ago a lot of time and

energy was spent with companies to persuade them to take on this role, but they appeared least interested. Of course they should because the faster an equipment is discarded and new purchased, the more money the company makes in an undisciplined economy.

Some years back, the trend in our mechanization effort has been to commission a group of consultants to conduct feasibility studies on a proposed project. While there are some reputable consultants who ensure the quality of their work before their names go on it, some of the feasibility reports which abound in our Ministries of Agriculture and Natural Resources are hardly of any value. There have been cases whereby some private businessmen involved with conducting feasibility studies had collected names and curriculum vitae of some experts and used such names to secure jobs and conducted the studies without the knowledge of the experts. Also some feasibility reports have atimes been over blown especially when such consultants have the hope of taking part in the implementation. An example of such projects was that of rice and maize production in a state. The project was scaled to grow 8, 000 and 4, 000 hectares of rice and maize respectively at the 10th year of the project. The project was to cost N77, 312,034.00. Two helicopters were to be purchased for the project. That was in the late 70's.

Also there were some World Bank loan partially financed agricultural projects, such as the Agricultural Development projects (ADP) in nearly all the states of the federation. Such loans are usually with a strong string even though the World Bank loan might not be more than 41% of the total cost. For the first phases of the projects, World Bank usually insists on having the key staff members to be expatriates. The basic salaries of such staff are usually very high while a Nigerian with similar or better qualification earns between 1 to 10% of the wages given to expatriates staff. Apart from the main salaries, a huge amount of money is usually lavished on the expatriates to provide infrastructures and other comforts. The results of such projects had hardly justified the huge amount of investment. In a sense, the expatriates take the lion shares of the benefit of the projects.

At times too, the expatriates insist on bringing most of the farm machineries and tractors to be used on such projects from their home country. And usually these brand of tractors and machineries might be those not popular in Nigeria, which means that all spare parts have to be brought from the expatriates' home countries and anytime there is a major breakdown the machines are usually grounded. In any way, the machines and tractors are finally laid to rest when the project terminates. Examples of such projects abound all over the country today. It is appropriate to mention here that another effort at Mechanizing Nigeria Agriculture is the setting up of the National centre for Agriculture Mechanization at Ilorin.

On July 29th, 1974, the Federal Department of Agriculture commissioned a study team on the establishment of the National Centre for Agricultural Mechanization (NCAM). The study identified adaptive research, equipment design, testing and training as the major activities of centre. The study also accorded high priority to land clearing, weeding, harvesting, crop processing, irrigation, the use of small – scale equipment, hand tools and animal drawn equipment. Sixteen years (16 yrs) after, the Decree No. 35 of 1990 which established NCAM was promulgated although the Centre started functioning from 1977. The general objective of the Centre is to accelerate mechanization in the agricultural sector of the economy in order to increase the quantity and quality of agricultural products in Nigeria. Specifically the Centre is to carry out the following functions:

(a) encourage and engage in adaptive and innovative research towards the development of indigenous machines for farming and processing techniques;
(b) design and develop simple and low – cost equipment which can be manufactured with local materials, skills and facilities;
(c) standardize and certify in collaboration with the standard organization of Nigeria agricultural machines, equipment and engineering practices in use in Nigeria;
(d) bring into focus mechanical technologies and equipment developed by various institutions, agencies or bodies and evaluate their suitability for adoption;
(e) assist in the commercialization of proven machines, equipment, tools and techniques;
(f) disseminate information on methods and programmes for achieving speedy agricultural mechanization;
(g) provide training facilities by organizing courses and seminars specially designed to ensure sufficient trained manpower for appropriate mechanization;

(h) promote co –operation in agricultural mechanization with similar institutions in and outside Nigeria and with international bodies, connected with agricultural mechanization.
(i) The Centre may carry out such other activities as are necessary or expedient for the full discharge of any of the functions of the Centre under this Decree. These functions if effectively carried out will achieve the miracle of transforming our agriculture.

However, the centre is not developing as it should. The status as of today is that it is not in position to start addressing the problems of mechanization in the country. It lacks the resources, (funds) research and engineering personnel, infrastructure, equipment, tools and instrumentation that can be used for studies and tests in agricultural mechanization. The board for this centre was just inaugurated on June 24th 1994. It is my prayer that the Centre will be able to take off properly now with the Board in place and the four resources persons on different aspects of mechanization, two are from Obafemi Awolowo University including the speaker.

SOURCES OF ENERGY IN AGRICULTURE

Man as energy source in Agriculture

Man as energy source in agriculture depends mainly on human muscle power and simple tools like cutlass and hoe. Under high temperatures and humidities man's work efficiency is usually less than 10% (Suggs & Splinter 1961) because of the inability of human system to be able to dissipate heat generated during working through evaporation, radiation or convection under these conditions. Also the laws of thermodynamics constrain humans and animals to low levels of food conversion to mechanical power. The efficiency of food conversion to mechanical power has been found to be relatively low under tropical conditions than in the temperate regions, hence justifying the need for even more auxiliary energy for agriculture in the tropics than in the temperate countries.

Researchers have shown that only 20 – 30% is used for body maintenance, growth, recovery from illness and waste heat. Man is thus limited to a continuous working rate of about 75watts. Agricultural works are usually carried out on soft and uneven surfaces. Walking on such surfaces consumed more human chemical energy than working on hard flat surfaces. For instance 391, 433, and 530 watts (Passmore and During, 1955) are required to walk on Asphalt surface, grass track and ploughed field respectively. Table 6 shows the rate of human chemical energy expenditure in agricultural operation in Nigeria

TABLE 6: RATE OF HUMAN CHEMICAL ENERGY EXPENDITURE IN AGRICULTURAL OPRATIONS. NIGERIA, 1954

Six subjects mean wt .55kg			
Number of observations	Activity	Kcal min	Mean energy cost Joules/s
12	Grass cutting	4.3	300
12	Bush clearing	6.1	426
12	Hoeing	4.4	307
12	Head carrying, 20kg load	3.5	244
12	Log carrying	3.4	237
10	Tree felling	8.2	572

Source: Passmore R. & During J.U.G.A. 1955
Human energy expenditure. *Physiological Review* 35 801-840

Human chemical energy expenditure of the order of 250 watts is considered to be relatively light work that can be sustained for a fairly long time while energy expenditure of the order of 450 – 500 watts are considered to be heavy work that may not be sustained for more than few minutes without rest. From this table it is obvious that tree felling and bush clearing are operations that require auxiliary energy input.

Analysis of monthly Agricultural energy requirements shows that agricultural energy requirement is far more than can be met by the human muscle most of the time. Agriculture is a seasonal industry where demand of energy fluctuates during the year. There are certain months of the year when agriculture demands more energy to meet requirements to complete crucial operations like land clearing and seedbed preparation. Figure 2

shows the seasonal power requirement for agriculture operations and human power available for a district in India.
This figure is strictly similar to what can be obtainable in Nigeria where in January to March land clearing and seed bed preparation are the main operations and power requirement gets to a peak during this period. Other peaks are during weeding, harvesting, processing and storage. The figure clearly shows that the energy produced by human muscle is grossly inadequate for agricultural production for most of the months except in December after all harvest are completed for cash crops. For cocoa farmers, this period is usually the peak of harvesting and processing. The curve will thus deveate from this.

Apart from the inadequacies of human energy as a power source on the farm in terms of quality, drudgery, hazards of exposure to body, irritating leaves, seeds, crops, insects, larvae, etc. are other limitations of the application of human energy on the farm. Also subjecting a certain portion of the body to severe stress for several hours can lead to much drudgery. For instance during planting of crops on the farm, the body may be bent for several hours. It is with the view of reducing this type of drudgery that Ige in 1976 developed a portable hand planter for grains. The device similar to a walking stick meters grains and plants them with minimum bending. This device was patented in 1981. Also the shelling of crops such as maize usually resulted in blisters in the hand and to reduce this, small simple hand Sheller were developed from pipes or sheet metals. These types of devices used to sell like cakes when our department participated at shows and trade fairs.

Animals as Source of Energy for Agriculture

The utilization of animals as power sources for agriculture in Nigeria has been limited to the high and low savanna zones. Their introduction to the rainforest zone has been hampered by the presence of tse – tse flies whose attacks on the animals are fatal. Other factors that have discouraged the introduction of animals in some of these areas are stated below:

(a) The cost of maintaining and feeding the animals is becoming prohibitive and the production from such animals just break even with the cost of feeding.

(b) The general shortage of protein particularly protein derived from meat in this region leads to stiff competition between the farmers and the butcners for the available animals.

(c) The animals are usually weak and mostly ill - prepared when they are required to give the maximum energy input. The peak energy input is usually required just after the dry season and this is usually the peak of food shortage as grasses, fodders and similar livestock feed are dried up. Generally, a cow can produce about 4 times the energy an average man.

TABLE 7: **Estimated Draught power of Various Animals**

Draught animals	Weight (kg)	Average speed of work.	Power development	
			(KW)	(HP)
Light horse	400-700	3600	0.75	1.00
Bullock	500-900	2160-3240	0.56	0.75
Buffalo	400-900	2880-3240	0.56	0.75
Cow	400-600	2520	0.34	0.45
Mule	350-500	3240-3600	0.42	0.70
Donkey	200-300	2520	0.26	0.35

Source: McDowell, R.E. (1975) UNPD/UNESCO/ICAR Project.

Table 7 shows the normal draught power of various animals. One horsepower is the power developed by a light horse working at average speed of 1 meter/ sec. Attempts have been made at the utilization of donkeys as draught animals. These animals are capable of providing only about 3 times the energy of an average man.

TABLE 8: Trials of Bullock Draught performance.

Type	Weight (kg)	Mean effort (kg)	Speed (km/h)	Power		Hours of work per day
				(kW)	(HP)	
Pair of white Peul Zebu Bullocks (Zaria)	780	110	2.3	0.69	0.93	4.05
Pair of N'Dama Bullocks (Farako-Ba)	720	100	2.9	0.79	1.06	2.15
Pair of Penitelo Bullocks (Kianjasoa)	1110	150	2.9	1.20	1.61	3.40

Table 8 shows results of the performance of bullock. The hours of work per day is about 4 hours or less. Also a pair of bullock generally does not produce twice the amount of power one bullock can produce. It should be noted that the production from an animal that can produce 3 times the energy of a man is usually substantially lower than 3 times lower than the production of an average man. Other limitation of animals is the unsuitability for some operations such as harvesting, post harvest handling and processing operations except in using them for transportation and for tramping over some crops for threshing. A similar curve for the monthly animal power requirements is given in Fiqure 3.
This also shows that animal power is inadequate for several months of the year.

Application of Commercial Power for Agricultural Production

Commercial sources of energy are those which are commercially produced such as fuels (diesel and petrol) chemical such as (fertilizer.

insecticide), electricity, transportation and machinery. Machinery inputs in agriculture are for various operations and handling. FAO reports indicate that rapid increase in commercial energy inputs are needed for substantial gains in agricultural production especially in developing countries where use of these inputs is very low. In 1972, the world average use of commercial energy on Agriculture was 3.5% of the total energy consumed.

The percentage use for North America and Africa were 2.8% and 4.5% respectively. This may give a false impression that African countries spend more energy on agriculture. The real value of energy consumed in North America and Africa were 2140×10^{15} joules and 70×10^{15} joules of fertilizers, herbicides, pesticides, irrigation and transportation, mechanization has been the medium for effective application of the energy inputs. For instance, there is no way irrigation can be effectively carried out without the use of machines. Machine inputs in irrigation includes machines for the construction of the water distribution channels, providing drainage, grading leveling and in pumping the water. A company like Okiti pupa Oil mills will not be able to get off the ground if the transportation of its palm bunches have not been machanized. Availability of yams from Suleija at Ife market is made possible by mechanization of the transportation system. We can go on with examples for the rest of the day to show that if developing agricultures are to progress, mechanization must be the strategy for the development.

Figure 4 shows the United State Agricultural production growth between 1775 and 1975, a period spanning over 200 years. For the first 90 years, the predominant energy inputs was human muscle (hand power) and productivity increased from 30% to 40%. For the next 70 years, the productivity rose from 40% to 55%. This was the horse power period. Towards the end of this period, mechanization took over and productivity increased from 55% to 120% in 40 years. The question should therefore be hunged on what form of energy to apply. For instance, tillage operations are great consumers of energy in agricultural production and the demand increase (approximately) with the square of the working depth. Hence doubling the depth of tillage increases the energy four-fold. The impact forces and the human work rate are such that the digging operations can be sustained only for 1 to 3 hours before resting for ½ to 2 hours with short breaks during the working period. Small tractors (<10kw) have been recommended atimes for tillage operations but low power tractors have low weight and hence do not have the ability to pull tillage tools that will be effective in our agricultural land which is atimes full lateral roots and stones.

Table 9 presents the farming operations for the major crops grown in Nigeria and the suitability of different power sources for such operations.

Commenting generally on this table, it appears that there is no alternative to the use of dozers either wheeled or crawler types for land clearing. The cost of using human labour for clearing 1 hectare of land is estimated to be about N1, 000 to N1, 200 depending on the density of the forest. The relative cost for mechanical clearing was about N600 to N700. (Ige, 1981).

For ploughing, harrowing, and ridging it appears that there is no alternative to double axile tractors if actually agriculture is to be mechanized. Human muscle as a power source is slow and inefficient, single axle tractor lead to much vibration.

Table 9: Types of Operations and Suitability of Power Sources.

Types of operation	Human Muscle	Animal Power	Single Axle Tractor	Double Axle Tractor	Dozers
Land Clearing	Slow & un-economical	Not suitable	Not suitable	For Savannah areas	For all types of vegetation
Ploughing	Slow and usually inefficient	Slow and generally not suitable for dry lands and soils with much roots	Much vibration. Not suitable for dry lands and soils with much roots	Suitable for most soil	Wasteful except virgin land
Harrowing	Generally not done	Slow	Generally slow	Suitable	Wasteful
Ridging	Slow and inefficient	Slow	Slow and much vibration	Suitable	Wasteful
Planting	Slow	Slow	Possible with appropriate planter	Suitable	Not suitable
Weeding	Slow	Not very suitable	Slow, appropriate only on mechanized farm	only on mechanized farm	Not suitable
Spraying	Slow	Not suitable	Suitable	suitable	Not suitable
Irrigation	Slow	Not suitable	Suitable	Can be adapted	Not suitable
Harvesting	Slow	Not suitable attachment	Lack of suitable attachment	Suitable for grain and have potential for other crops	Not Suitable
Primary processing	Slow	Not suitable	Suitable	Suitable	Not suitable
Transporta-tion	Slow	Relatively better	Can be useful	Suitable	Not Suitable

For instance, it was an unconfirmed statement that a single axle tractor imported into the country by the Federal Government from China was once given to a selected farmer. The farmer was told to keep the machine if he liked it and found it useful. The For instance, it was an unconfirmed statement that a farmer returned it after using it for about 30 minutes, with a comment that he did not want to die immediately.

About 28 years ago, engineering students, were trained on slide rules. Engineers were then identified by their slid rules always attached to their uniform. Today, it will be absurd to see an engineer carrying slide rule because technology has moved and we are now at the age of "Note books" which are extremely portable personal computers. So it is in mechanization today, that technology has moved from the use of cutlasses and hoes to giant tractors which are up to 750 h.p and other farm machines. It is thus technologically very absurd that our farmers are still today depending on cutlasses and hoes for their farm operations.

Contributions to Agriculture's Machinery Development

In the developed countries, considerable effort is being spent on the optimization of the performance of already developed machine, with the ultimate aim of effecting modifications that will increase the energy efficiency. In one of such efforts, a comprehensive study was carried out on forage harvesters. The forage harvester was one of the high energy consuming machines on a modern farm. The cutterhead unit was the most energy-consuming unit and hence some fundamental studies were conducted to understand that operation of the harvester. Up till 1975, there was lack of knowledge about the nature of the forces developed during cutting and the response of the knives to these forces. This had made the evaluation of the performance of forage harvesters difficult. Attempts had been made by prince *et al* (1958) and Chancellor (1958) to measure the cutting force. But the usefulness of their results was limited by the fact that they worked at very low knife speeds and cut single or very few stems. These conditions were far different from the actual operating conditions of a forge harvester.

Ige and Finner (1978) studied forage harvester knife response to cutting force of a deep layer-forage with a two knife cutter head, powered by an electric motor. The knife supported were instrumented to measure cutting forces and forage at different moisture levels were made at the various knife speeds. Mathematical equations were developed for the response of the knife to the cutting force. The resultant equation was a second order differential equation. The experimental measurement of the response verified the adequacy of the equations. The effects of the vibration on the performance of the cutter head were not advantageous, especially as it affects the clearance distance. Clearance distance was noted to affect the quality of cut greatly; generally there was more bruising and bending of the forage at increased clearance distance.

Also levels of understanding of the shearing characteristics of forage harvesters were such that only vague ideas could be given about the effects of the design factors on forage harvesters up till 1975. Many investigations have been made on the shearing energy, but the usefulness of the results have been limited by two main factors; the first being the experiments themselves and the second being the mode of the date collection.

Most experiments have been conducted using pendulum type apparatus and cutting one or very few stems. While it was doubtful that the pendulum represented the shearing process in the forage harvester, it was even more doubtful that cutting only one stem or very few stems represented cutting deep layers of stem. Cutting of one stem would approximate double edge cutting, while cutting deep layers was a combination of both single and double edge cutting. Also most investigators have conducted invariant experiments. Such experiments made it difficult to obtain the interaction between the factors and hence almost impossible to show the complete response surface.

The power required to operate a forage harvester is composed of five component parts (Kepner *et al*. 1972):

(a) To drive the feed mechanism,
(b) To shear the forage,
(c) To accelerate the forage,
(d) To move air in the cylinder,
(e) To overcome friction of forage against stationary parts of the machine.

Isolation of the shearing energy from the other five components has been of concern especially when knowledge of these components was not adequate to enable accurate predictions. Hence, the shearing energy data obtained by subtracting the five other computed energies from the energy used to drive the cutter head became of doubtful accuracy due to the masking effects of these other components.

To eliminate the masking effects these five other energy components on the shearing energy, Ige and Finner 1975 modified a forage chopper and instructed it such that the force-displacement curve for a knife could be plotted directly. From curve, the shearing energy per cut was computed. A 2^6 factorial experiment was designed for six of the factors that have been identified as affecting the shearing energy requirements. The results show that interactions as well as main effects significantly effect the shearing energy requirements.

The results of these experiments and the analyses from Liljedahl: *et al* (1961), on the effects of the moisture content, the clearance distance and the knife dullness seem to agree strongly. Both showed that the moisture content affects the shearing energy substantially when the energy used in units of energy per unit wet weight but does not have a significant effect when the energy was in units of energy per unit dry weight. The results showed that the shearing energy was not affected as much by the clearance distance as it was by the knife dullness.

But the two factor interactions between these two factors appear very significant. The shearing energy was affected mostly by the rake angle and the lip angle of the knife. The two factor interactions between these factors and some of the other factors were found to be important when the energy was expressed per unit of either dry or wet weight. However, observations during the experiment show that increased clearance distance and dullness affect the quality of cut adversely. The forage was badly bruised with increased clearance distance and dullness. Some forage stems nearest to the shear bar were bent over the shear bar and remained uncut. In some instances, the cutter head pulled some stems through without cutting.

Particle movement through the cutter head of a cylindrical type forage harvester was studied by Ige and Finner in 1975. Prior to this time, there was lack of adequate knowledge about the path of flow of particles and parameters that affect the flow. Thus hindered the optimization of the performance of the cylindrical type forage harvester and has been a limiting factor in predicting accurately the frictional energy requirements of the harvester.

In 1954 attempts were made by Barrington *et al*. (1953 - 1954) to evaluate the frictional resistance to material flow. Similar work was carried out by Blevins and Hansen (1956)Their calculations were based on the weight of the materials, centrifugal acceleration, the angle of wiping contact and the coefficient of friction between the material and the housing. Richey (1958) commented that the path of flow based on the above calculations varied substantially from the actual path of the material flow.

In studies made in Germany on the cut – throw type of cylindrical harvester by Kromer (1969), it was shown by equations and high-speed motion pictures that the particles were thrown after they were cut. Earlier studies in this area had noted that the particles were dragged through the housing until discharged.

In the work of Ige and Finner (1975), Newton's Law was applied to develop the momentum relationship which was then used to derive the velocity of the particles after impact. From the velocity equation, the limiting condition for the particles to be thrown was derived. Since this condition was not always satisfied, equations of the particle on the knife were developed. These equations were verified with the aid of high-speed motion pictures and by recording the knife at various knife settings.

The adequacy of the developed equations for the particle motion in cylindrical type forage harvester was substantially supported by high-speed motion pictures and the knife response curves. This study shows that the smaller the rake angle, the better is the chance of the particles being discharged quickly from the surface of the knife. As the primary function of the knife is to cut the forage, and it is suspected that the cutting force increases when rake angle decreases, hence, it remains to be determined if quick discharge from the knife could be an advantage to the overall performance of the knife. If it was not an advantage, perhaps the best-compromised knife setting could be obtained or an improved design could be made. This necessitated more probing and this was carried out by Ige and Finner in 1976 in their study on optimisation of the performance of the cylinder type forage harvester cutterhead.

This study attempted to describe the mechanics of forage shearing and mathematical models for shearing energy based on the developed mechanics and the conclusions reached by Ige and Finner (1975a, 1975b, 1976) The constants for the mathematical models were evaluated from experiments for whole alfalfa and corn stalks without ears. Some experiments were conducted on commercial forage harvester to substantiate some of the conclusions of the study.

The summary of analyses of results for cornstalks were such that the optimum setting for the knife dullness was zero but that of the clearance distance was 0.15 cm. This suggested that unlike alfalfa some clearance distance could be maintained while shearing corn stalks. This result was speculated by Cshancellor (1958). The optimum lip angle was surprisingly large (about 55 deg) while the optimum rake angle setting was about 90 deg.

The results of the other local optimum settings for corn stalks show that lip angle and rake angle of about 90 deg each gave optimum settings for corn stalks of about 45 percent moisture content. But the shearing energy increased rapidly when the knife was inclined at rake angles much less than 90 deg. And also when the knife became dull. The knife dullness did not seem to affect the shearing energy appreciably when the lip angle and the rake angle were both 90 deg. Also shown is that clearance distance was not very critical when shearing corn as compared to shearing alfalfa.

All of the analyses for alfalfa and corn stalks suggest strongly that for efficient shearing, the knives should be set such that the rake angle is as close as possible to 90 deg. However, the results of previous study (Ige and Finner 1975B) on the particle motion showed that the rake angle should be at the most, 45 deg. For the particles to be thrown. The optimum conditions for shearing and moving of both alfalfa and corn are thus opposite.

The optimum settings for the cutterhead are those which shear and move the particles most efficiently. A possible solution to the problem of shearing and moving the particles efficiently is by using 'J' knife design such as used in the John Deere 3800 forage harvester. Previous studies show that the particles were not thrown immediately after they were sheared but instead they expanded to a grater surface area of the knives. It was conceived that the 'J' knife has potentials for orienting the cutting part of the knife to a rake angle of nearly 90 deg. After shearing, the particles would conceivably expand to the other portion of the knife which could be made as closely as possible to a rake angle of 0 deg.

A few experiments were conducted to study the shearing and moving processes of the John Deere machine. High-speed motion pictures of the processes were taken. Total PTO torque to drive the machine and PTO speed were measured. Measured weights of forage were spread uniformly on a measured length a conveyor that fed the cutterhead. The blower and its feed auger were disconnected in these tests. The machine was set for a theoretical length of cut of 0.95 c.m.

The moisture content of the corn was 64 percent (w.b). The cutting energy in joules per 5×10^{-4} KG of materials were computed from the above data. The theoretical shearing energies were computed from earlier equations derived. The kinetic energy imparted to the sheared particles was computed using the velocity equation from previous study (Ige and Finner 1975b). The shearing energy was adjusted for the 0. 9 5cm theoretical length of cut. The shearing and kinetic energies were added together and compared with the measured energies. The results of the experiments with the John Deere harvester and the computed results from prediction equations the results appears close showing that the developed equations could be used to predict the cutting energies to a fair degree of accuracy. The computer results for corn, though close seem to be consistently higher compared to the experiment results. This perhaps, was due to the fact that the equations were developed for corn stalks without ears; whereas, the experiments were conducted with stalks with ears.

It is gratifying to note that this paper was rated as one of the top 17 papers in all the over 400 papers published by America Society of Agricultural Engineers in 1976. The paper was accorded Honorable mention for its outstanding contribution and engineering merit.

In Nigeria traditionally, cowpea pods are harvested and threshed manually. The threshing is usually done by beating the pods with clubs on uncemented floor. Though not documented, much damage results from this uncontrolled beating. Also during this process stone and other dirt particles readily mix with the grains, thus resulting in produce of low quality.

After threshing, the grains are separated from the chaff manually with the aid of a calabash. This is carried out by tossing the mixture of the grains and chaff up and down in the calabash in such a position that the wind blows across the tossed particles. The chaff is blown away while the grains drop into the calabash. Another popular traditional method of separation is to throw the mixture with some force; the chaff usually drops nearest to the thrower.

This traditional method of threshing and subsequent grain separation is physically demanding on the persons usually women, performing the operations. The method does not encourage high production and often results in a low quality product. Unfortunately, the small holdings of Nigerian farmers do not justify investment in big machines like the combine harvester, which in any case had not been adapted for such local crops. The uneven maturity of pods and the lack of mechanized land preparation are other factors which make the operation of such machines on the small farms difficult. However, there was a growing need to reduce drudgery and improve the quality of threshed cowpea by providing farmers with an appropriate thresher which was aimed at meeting their needs. To this end, a mechanical thresher was designed and built by Ige in 1978.

The threshing and separation performance of the built cowpea thresher was evaluated. The results showed that the speed of the drum affects the threshing efficiency of cowpea. Also the results indicated that moisture content has an effect on threshing efficiency, mechanical damage and separation loss but owing to the small range of moisture for each variety no decisive conclusions about the effect of moisture for each variety could be drawn. A threshing efficiency as high as 99% was obtained for samples with the least moisture content in each of the 3 varieties studied at beater speeds of 500 rev/ min and over. A drum speed of 500 rev/min appeared to be the optimum in order to obtain the highest percentage of threshed and undamaged seeds. The speed of the fan should be set at about 1400 rev/min for the least separation loss without undue clogging of the chaff outlet for Ife brown and H64 – 3 varieties. In order to be able to thresh and separate successfully other varieties of cowpea such as IVU-37 whose grains are small compared with those of Ife brown and H64 – 3, a baffle was arranged at the chaff outlet and the separation loss was reduced from about 16% to about 5% at a fan speed of 1400 rev/min.

Ige and Ajayi (1982) further developed this thresher to improve the efficiency. After three developmental stages, a simple and effective cowpea thresher evolved. The machine as developed is capable of threshing a bag of cowpea in an average of 3 minutes with only one operator. This compared favourably with the first model which took an average of 9 minutes. Other advantages of this model are shelling efficiency of about 100 % low cost of construction and materials of construction and only one rotating shaft as compared to two rotating shafts in the other models.

Nigeria government has in the recent years spent a colossal amount of money on the installation of strategic grain storage facilities all over the country. These grain storage silos are carbon copies of what can be popularly seen in Europe and America. Grains are living matters and thus response positively to the environmental conditions. Since the environmental conditions (especially temperature and humidity) in the tropics are largely different from those that obtain in the tropics, the grains stored in this silos cannot be of similar quality after storage. Indeed the experience so far is failure. Apart from these environmental differences which dictates strigent control and maintenance, operations, the required precautions even in temperate environment are not adhered to in most of the sites.

Apart from the basic functional aspects of the silos, there is concern that the once quiet environment in which farmers performed their operations may be polluted with high noise levels which are not only disturbing but can be injurious to their health. The noise levels appear to be increasing as bigger and more powerful machineries are introduced to increase productivity on the farm. Since it is expected that the trend towards mechanization on the farm will continue and public awareness to environmental problems will increase, it is on this note that agricultural engineers always look into practical ways reducing noise from farm equipment.

In the area of processing, crop-drying fans are among the noise offensive machines. Dryer installations have their fans ducted to the bin, which contains the crops. With this type of construction the associated noise problem is limited to the inlet are of the fan since most of the outlet noise is absorbed through the layers of the crop in the bin. Thus any control measure that could reduce the noise in the inlet region of the dryer would be quite effective. The noise transmitted through the bin is usually not high enough to be of concern.

To assess the usefulness of any remedial measure applied to noisy equipment, it is necessary to compare the noise level to the existing criteria where none of the existing criteria or legislation apply specifically to farm equipment, useful inferences can be drawn from the existing Federal legislation (OSHA, Occupational Safety and Health Act), criteria set up for similar industrial equipment, the known effects of noise on human beings, and the operating environments of dryers to set up the noise criteria. Present knowledge on effects of noise on man indicates that hearing damage is the most hazardous. But other effects such as speech interference, sleep disturbance, and general annoyance should be considered in the criteria as dryers are often installed near residential areas.

Considering the hearing damage criterion, OSHA regulations could be used to prevent impairment to the ears. Thus, for eight hours of exposure per day, the noise level of the dryer should not be more than 90 dB (a) at a worker's location which conservatively is assumed to be 10 m from the noise source.

Generally, noise can be reduced at three locations: the source, the path, and the receiver. Design changes such as unequal spacing of the fan blades could only decrease the perceived noise level by the modulation of the pure tones but the overall sound pressure levels remained the same (Mellin and Sovran 1970 and Ewald *et al,* 1971) Removal of all obstructions to the path of flow in order to eliminate the sources of turbulence would change the performance characteristics and also remove the beneficial effect

of mixing the heated air before it passes to the crop. Hence Ige and Finner (1974) in their work decided to intercept the path of the noise. This was done by absorbing and reflecting the noise energy through the use of mufflers and cones filled with fiberglass. These practical noise control devices were installed on the axial flow fan and the results were evaluated using statistical methods and compared with established criteria.

The results show that aerodynamic noise from crop drying fans could be reduced by using mufflers and cones lined with fiberglass as the absorptive material. Observations and results obtained using different cone diameters showed that the noise level was more uniformly reduced all around the fan once the line of sight of the fan blades was completely blocked by the cone. In another study on fans, Ige (1981) studied the effect of double air inlet area on the performance of a type of centrifugal fan. Conventional radial fans are substantially different from the radial fans found on farm machinery and processing equipment. Some of these differences are:

1. The geometric ration of their dimensions.
2. The mode of air intake either single or double entry locations.
3. The different types of obstacles in the flow path.

The performance of the radial centrifugal fan with double entry locations (entry of air from both ends of the fan) on a locally built cowpea thresher was studied with the acetylene flame from a torch and by measuring the flow along a cross – section at the fan outlet while varying the inlet area and the fan speed.

Obstacles such as bearings, pulleys and supports around inlet area of fan leads to eddy formation around the obstacle and hence head losses in the fan.

A thin layer of air just above the fan shaft moves round it in helical formation. Just above the helical layer, air is drawn in straight into the fan, the nearest layer of air to the helical layer moves farthest into the fan before rotating through 90% into the impeller inlet area.

The air appears to be further rotated and pushed around the fan casing until forced into the discharge. Air drawn in from both sides may collide inside fan causing losses or the fan may be too long resulting in starvation in some section of the fan.

The proportion P of the total end area available for air inlet appears to influenced the flow in the fan considerably. The condition in which P = 0.6 gave the optimum overall velocity head while the flow appears more uniform in the outlet when P = 1.0.

MECHANISATION OF THE PROCESSING OF TROPICAL FARM PRODUCE

In Nigeria and many tropical countries, yam *(Dioscorea spp.)* tubers are major sources of food. The tubers are sometimes cooked, roasted or cooked and pounded for food. At times, they are processed into flour or flakes and prepared as "amala or pondo yam". Some Nigerians usually regard their diet incomplete without eating yam tubers either in the cooked or cooked and pounded form once in a day. These preferred forms of yam food are usually prepared from the tubers and this necessitates the preservation of yam tubers from one season to the other.

Adesuyi 1973 studied curing of yam tubers under temperatures ranging from 25^{0}C to 40^{0}C and humidities he described as low and high. His results showed heavy mould formation at low humidity for all temperatures investigated but the weight losses were highest at low humidities. In storage he indicated no incidence of mould formation in the tubers cured at low humidity after twenty weeks in storage.

Martin (1974) experimenting with *Dioscorea bulbifera* and *Dioscorea esculenta* conluded that the protective layer call "periderm" may not occur after wounding. Passam *et al.* (1976) reported periderm formation in deep wounds such as bisection but no such formation was experienced in superficial wounds such as peeling and abrasion. They warned against curing and storing of tubers that have been damaged superficially as they tend to lose a lot of weight and also deteriorate rapidly in storage.

The results of these various researches have not been too encouraging to generate confidence in the large scale application of high rate of mould and rot development and also because of high percentage weight loss during curing and in storage.

Ige (1979) studied the effects of moisture and humidity curing. Coatings with soils and paints were also carried out.

The following conclusions were reached:

1. Curing under high humidity and high temperature has potentials for curing and for preventing mould formation.

However, mould formation usually occurs before curing takes place resulting in spoilage.
2. Applying low humidities in curing results in drying rather than curing. This probably explains high weight loss experienced by Adesuyi (1973) at low humidity. Drying normally leaves the injured surface porous. The hardness of the drying surface depends on the rate of drying. The higher the rate of drying, the harder the surface. Rate of drying under and condition decreases as the drying progresses into the interior of the tuber and hardness usually decreases from the injured surface to the interior.
3. Drying usually leaves a surface still porous enough for mould penetration.
4. Coating wounded yam surfaces has high potentials for curing the wounds without developing moulds which had been usually experienced when wounds were cured with high humidity and high temperature.

The processing of yam tubers were also studied:

Yam tubers are processed into several products for storage. The most popular products are 'Poundo Yam' (Cadbury Nigeria Ltd.,), pounded yam flour (a product of the Food Science and Technology Department of the Obafemi Awolowo University, and yam flour (Elubo) produced by farmers using traditional techniques.

The first two products are attempts to prepare instant foods which reconstitute into products very similar to the traditional pounded yam which is one of the most highly favoured items of diet in West Africa. The third product called 'Amala' in Yoruba when prepared is different from the first two products in colour, taste and testure.

The processing of yam tubers into yam flour is a long established practice in Nigeria, especially the Western State, the neighboring countries, but the method has never been fully investigated scientifically to determine the parameters that affect the quality of the product. For instance, during the parboiling stage the local processors usually determine the parameters that affect the quality of the product. For instance, during the parboiling stage the local processors usually determine the parboiling temperature subjectively by dipping their hands into the pot, a procedure which is clearly unacceptable for large – scale processing.

The need to modernize this method by developing appropriate machinery and equipment for processing and handling of the products calls for some basic studies into the parameters that affect the product.

These parameters were studied by Ige and Akintunde (1981). The study showed that the time needed for processing yam tubers into yam flour can be much reduced if the process is mechanized.

Parboiling is an essential element in processing yam tubers into yam flour, locally called 'elubo'. A flabby texture of parboiled yam pieces indicates that they are adequately parboiled. The parboiling temperature should be undertaken at about 60^0C. The parboiling time required depends on the thickness of the yam pieces, governed by the equation

$T = 3.5 + 8t$. The temperature should be between 60 and 80^0 to obtain a fairly brittle product which will mill easily into powder form. Above this temperature the product becomes brownish and the grains are coarse.

Rice in Nigeria has been a source of food of unique importance to the economy of Nigeria. It is a top favourite even in areas where pounded yam has once been the predominant dish. The crop is widely grown in the country, however consumers prefer the imported rice because of the convenience of preparation rather than its palatability. The imported rice is usually clean, hence can be poured into the cooking pot directly from the shelf without further cleaning before cooking. The drudgery of picking the dirt and the time spent in the exercise are among the factors that make the modern housewife prefer the imported rice. This general preference of the imported rice has reduced the demand for locally produced rice and hence production of rice has dwindled considerably since Nigeria started massive importation of rice (N 176 million was spent on importing rice in 1978). This situation is of grave concern to the Federal and State Governments. There is thus urgent need to improve local processing technique if adequate dividend is to be realised from investments on rice production. Ige and Igboanugo 1981 studied the factors affecting the local and improved methods of processing rice. The absorption of moisture during steeping at room and elevated temperature and parboiling by steaming and boiling were evaluated. A factorial experiment was designed and carried out to evaluate the effects of steeping time, mode of parboiling and mode of drying on the husking, broken and yield percentage.

The result show that an optimum temperature of steeping is between 55^0C and 65^0C for the varieties investigated and that broken and yield percentage were significantly affected by the steeping time.

Time will not permit me to go into details in my collaborations with my other colleagues on the mechanization of different other crops. To mention a few, the work of Babatunde and Makanjuola (1988) on oil palm processing are summarised in two publications and the recommendations from this work if followed have tremendous potential s for increased fruit recovery from oil palm bunches and increased oil yield. Also, a modified low cost palm oil extraction process was studied by Babatunde, Ajibola and Ige. The achieved extraction efficiency was 87%

All these efforts have been carried out with the firm believe that mechanization is the key variable in the equation for agricultural production and processing. Processing. Professor Makanjuola in the concluding remarks in his inaugural lecture stated "it is reasonable and logical to expect that the techniques, the resources and the opportunities for production in Nigerian Agriculture are bound to change in order to increase the volume and quality of output of crops and livestock products". Seventeen years after, this reasonable and logical expectation has not been realised. Then he predicted that " It is my humble prediction that the only other alternative to the expected favourable change in our agricultural fortunes in this country is a progressive escalation in the cost of food culminating ultimately in a famine". Today, his prediction has been fulfilled. There is no honest worker in the country today that can boast of decent standard of feeding and living. The once scaring 0:1:1, 1:0:1 mode of feeding has come to stay with us permanently. Indeed it has yielded in some families to 0:0:1 even after spending up to 75% of their salary on feeding. The effect of this on individuals is that our ability for physical work is dwindling at a fast rate, intellectual capabilities and alertness are diminishing and our resistance to diseases is very low.

RECOMMENDATIONS

(1) On the local level, it is important and crucial that University authorities recognize the important roles a department such as Agricultural Engineering should play in the drive for increased agricultural product. These roles go beyond teaching and research if the Department is to participate actively in the Mechanization

March. Therefore, our staff strength should not be based on the FTE alone. I will like to suggest an additional factor, National Economic Factor.

(2) The agricultural production level in the country today is at a precarious level and the situation will become worse unless some measures are taken to attract people to the farm. One of such measures is to evolve a fiscal policy in our national budget that will reduce the price of agricultural inputs to as low as 5% of the present cost. For instance tractor cost should be reduced from the present price to about one million naira to about N10, 0000. All over the world food, is regarded as a security stategy and nations that wanted the development and had developed put priorities on techniques of achieving higher agricultural production. Hungry populace cannot develop a nation.

(3) The National Centre for Agricultural Mechanization in Ilorin should be regarded as a Federal Government priority project. Funds should be made available to get the Workshop which is nearing completion well-equipped and appropriate instruments acquired for a sustainable mechanization programme. The staff situation should be considerably improved and the working conditions enhanced to high productivity. The staff situation should be considerably improved and the working conditions enhanced for high productivity. The centre should have about 30 researchers, 24 research technician and 5 design engineers all working on the various aspects of the Mechanisation programme. The level of government funding and support should be such that they are capable of throwing a five-year challenge for the mechanization of our agricultural systems.

(4) The Federal Government should through the Federal Ministry of Agriculture–Engineering Division Commission a study team of experts on the stategic grain storage sites that are built all over the country with a view to making all necessary recommendations and modifications that will enhance the functional utility of the immense investment.

CONCLUSION

In conclusion, I have endeavored in the course of this lecture to emphasis the need for grater energy input into our agricultural system and that all form s of energy are better applied through mechanization. Indeed, the only alternative to mechanization in agriculture is famine and ultimately poverty in all its ramifications: the threshold of which we are in today.

While continuing with activities that will enhance the mechanization of Agriculture in Nigeria, I am hoping for brighter days ahead when Agriculture will be compulsorily mechanized. For it is written *"And they shall beat their swords into plowshares, and their spears into pruning hooks; nation shall not lift up sword against nation, neither shall they learn war any more"* Isaiah 2:4 "*He that tilleth his land shall be satisfied with bread*" Proverbs 12:11. It is going to be 1000 years of peace and abundance. I pray that we all take part in this peaceful reign.

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