ERGONOMIC STUDIES AND IMPROVEMENT ON TRADITIONAL OIL EXTRACTION OPERATIONS

BY

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(NOVEMBER, 19 97)

DECLARATION

I, the author of this work, hereby declare that this thesis is a record of my own research work. It has never been presented in any previous application for higher degree, or for publication. Information extracted from printed literature and used for review purposes are duly acknowledged by means of references, and the author(s) specifically credited.

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CERTIFICATION

This thesis, entitled "ERGONOMIC STUDIES AND IMPROVEMENT ON TRADITIONAL OIL EXTRACTION OPERATIONS" by M.A. Sanda, meets the regulations governing the award of the degree of Master of Science (Agricultural Engineering) of Ahmadu Bello University, and it is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Ergonomic principles were used to develop simple tools for kneading, deskinning as well as rolling and cutting operations in traditional groundnut-oil extraction process. Attempt was made to quantify amount of water required during the kneading process.

The developed kneading mechanism allows for operation in a comfortable sitting posture. It gives a higher extraction efficiency (0.5 - 0.9) compared to the IAR Modified Pestle (0.1 - 0.7) and the Traditional pestle (0.5 - 0.1 , for groundnut quantities ranging from 2.2kg to 6.6kg. The developed kneader also resulted in reduction of energy expenditure in the kneading operation. For example, for 6.6kg of groundnut, reduction of energy expenditure was 37.36% and 32.41% compared to the Traditional Pestle and the IAR Modified Pestle respectively. In addition, operational time was reduced by between 33.0% to 52.17% or 3.3 min/kg to 5.5 min/kg, depending on quantity of groundnut.

The Improved IAR Deskinner virtually eliminates the winnowing process, and allows for operation in a comfortable standing posture. Groundnut deskinning with the improved deskinner requires 1.1 min/kg, compared with 2.3 min/kg with existing tool, resulting in time reduction by 52.17%.

The Developed Cake Roller/Cutter resulted in an operational time reduction of 62.0%, when compared to the use of hand.

Correlation analysis of weight of water added and quantity of groundnut kneaded gave a correlation coefficient of approximately 0.99 for each of three different tools used. Also, regression analysis of the relationship indicates the existence of a model linear regression equation linking the two quantities.

System analysis, taking into consideration various options for processing groundnut (from roasting to frying), showed that by using devices developed above, total operational time was reduced by upto 38.3%

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ABBREVIATIONS

ABU	Ahmadu Bello University
ATP	Adenosine Tri-Phosphate
BMR	Basal Metabolic Rate
CBN	Central Bank of Nigeria
DF	Degree of Freedom
FAO	Food and Agricultural Organisation
F	Fisher's Value
IAR	Institute of Agricultural Research
IDRC	International Development Research Centre
IITA	International Institute for Tropical Agriculture
ILO	International Labour Organisation
MS	Mean Square
SEDIAC	Society for Education and Development in Industry, Agriculture and Commerce
SP	Sum Product
SS	Sum Square
UNDP	United Nations Development Programme
UNIFEM	United Nations Development Fund for Women
USA	United States of America

CHAPTER ONE

INTRODUCTION

Groundnut, which traditionally constituted an important component of Nigeria's export, has shown a decline from 18 percent in 1968 to virtually no exports at all in 1975 (CBN, 1976). This situation could be attributed to decrease production and increase in population. As population and incomes of Nigerians increased, the proportion of the crop consumed locally also increased (Abalu, 1978). Most of this domestic consumption takes the form of locally processed oil and cake. Groundnut-oil is an important ingredient in the diet of many Nigerians. Groundnut-oil is the leading vegetable oil that is processed mostly in the Northern parts of Nigeria. The oil and fried cake (Kulikuli) are generally sold in bulk to retailers, or are retailed by children and adult women (Dunmade, 1991). Thus groundnut-oil processing is an important income generating activity.

The operations constituting traditional groundnut processing start with shelling of the dried groundnut kernels to remove the seeds. The seeds are then roasted to facilitate the removal of their skins through winnowing. The deskinned seeds are then ground (milling) using a variety of tools to form paste. The paste is then kneaded to extract the oil. The oil is clarified by boiling and the residue (cake) is hen shaped and fried in the oil to form kulikuli.

Dunmade (1991) reported that, women dominate the traditional groundnut-oil extraction industry in Nigeria. She reported that out of 436 processors interviewed in three Northern states of the country, namely; Kaduna, Kano and Niger, 75 percent claimed that they were processing for income generation. All respondents used traditional tools and methods which normally involve high drudgery, resulting in greater man-hour requirement for completion of tasks and/or incomplete oil extraction. Seventy-three percent indicated their preference to increasing productivity by using improve equipment rather than allocating more time to the processing.

Another study on traditional systems of groundnut-oil processing in Nigeria by Nalumansi and Kaul (1992) identified operational constraints, like high level of drudgery to be associated with some of the processing techniques. Hence they recommended that for higher productivity of the traditional processing methods and enhance quality of the products, the following parameters require due consideration.

(i) Elimination or reduction of the drudgery involved in the kneading operation;

(ii) Standardization of the size and shape of groundnut-meal pieces and the incorporation of a low-pressure oil extraction mechanism at the forming stage (i.e. elimination of secondary extraction);

(iii) Standardization of the amount of salt and water added at the beginning of the primary extraction process;

(iv) Elimination or reduction of delays inherent in the entire processing periods;

(v) Accomplishment of a thorough emptying of the mill by washing out the remnants of the milled groundnut with water which should be part of the amount required in the kneading operation.

Nalumansi and Kaul (1992) attempted to lessen the drudgery involved in the traditional kneading operation by designing a Modified Pestle for use in conjunction with commonly available mortar. Available small-scale mechanized equipment for groundnut-oil extraction are imported and the prices quoted ranged from eleven thousand to fifteen thousand naira, which was too high for an individual traditional processor to afford.

Considering the importance of this activity as a revenue generating source for many women and a gateway for an important component of our diet, this work is aimed at improving the various tasks that constitute the process. This is with the belief that production ability of the traditional groundnut-oil processors could be enhanced by designing affordable efficient tools and/or methods to

reduce time and the high level of drudgery involved in some of the tasks. Common approach is to start with a thorough scientific investigation on the methods and tools used in the traditional processing system, in order to ensure the evolution of appropriate solutions.

In this regard, ergonomic studies need to be carried out on the entire traditional-oil extraction system with the aim of assessing the degree of compatibility between the tools in use and their users. This study will reveal kind and types of limitations and constraints imposed by the tools and/or methods on the operator, and how these limitations and/or constraints contribute to the drudgery levels and man-hour requirements for specific methods in the extraction system.

The objectives of the work include to:

1. perform ergonomic studies of present methods/tools used in groundnut-oil processing;
2. identify areas of constraints/intervention to upgrade present process;
3. develop improved methods/tools to remove identified constraints;
4. compare improved methods/tools with existing processes.

CHAPTER TWO

LITERATURE REVIEW

2.1.0 TRADITIONAL FOOD PROCESSING IN NIGERIA

A study by IDRC (1973) found that in the northern parts of Nigeria where grains are much more predominant, it is women who mostly engage in the processing of groundnuts. The study further revealed that 78 percent of rural women engaged in food processing use traditional technologies that are labour consuming. According to Erinosho and Fapohunda (1989), traditional food processors see the business as laborious, unprestigious and would not like their children to undertake it as a career. Dunmade (1991) found this attitude to be understandable after considering the fact that most food processing activities in Nigeria are still carried out with traditional technology which requires a lot of physical energy input. This situation, according to Dunmade (1991) underscores the need for the use of simple appropriate technologies that will ease the hard labour required in food processing enterprise.

2.1.1 FACTORS AFFECTING TECHNOLOGICAL INTERVENTIONS

An improved technology, according to UNIFEM (1987) may prove to be inappropriate for social, economic, cultural or environmental reasons. It was observed that technologies which are not based on a good understanding of traditional processing techniques tend to have a low acceptance rate. Also, lack of infrastructural support and services as well as the inability of the user to maintain and replace parts

using locally available resources and skills at affordable price results in non-acceptance of an improved technology (UNIFEM, 1987). In addition, UNIFEM (1987) has established that economic factors are often a constraint to the adoption of improved technologies by traditional processors as a result of their being denied access to formal lines of credit, because of their inability to provide collateral.

In this respect, UNIFEM (1987) has established that the introduction of any appropriate and acceptable processing technology, especially for traditional food processors who are mostly women, requires a thorough understanding of the socio-economic and cultural relations of the users. This implies that before attempts are made to introduce improved tools and methods for oil extraction, according to UNIFEM (1987), an effort should be made to understand the traditional methods being employed (UNIFEM, 1987). This call for the conductance of socio-economic research alongside technical research, if technologies which seem to be applicable, relevant and acceptable are to be introduced. There is also the need to pay attention, not only to identifying the wants, needs and problems of the traditional processor, but also to the possible consequences for the end users (UNIFEM, 1987).

2.2.0 GROUNDNUT: Types, Production, Processing and Trade

Groundnut, also referred to as peanut is a nourishing food. More than a quarter of groundnut is protein whilst about half is oil. Thus the importance of groundnut

production and processing in Nigeria, according to Abalu (1978), lies not only in the crop's role as a key foreign exchange earner, but also in its role as a source of protein to meet the inadequate diet of Nigerians and an important source of supplementary feed for a growing livestock industry.

Groundnut is a crop belonging to the leguminosae family. Its cultivated variety is the Archis Hypogaea. The multiple nourishing value of groundnut offers a wide range of food and industrial products among which are:- the whole groundnut; : groundnut oil; the groundnut paste; and the groundnut cake (SEDIAC, 1978).

2.2.1 Origin

Historically, according to Hammons (1973), groundnut was supposed to have been introduced into the West Coast area of Africa at the beginning of the 16th century by the Portuguese, and also into the Philippines by the Spanish. It was then presumed to have spread from the Philippines to China, Japan, South-East Asia, India and the East Coast of Australia. It finally reached Madagascar as well as the East Coast of Africa from Sri Lanka or Malaysia, presumably. Subsequently, groundnut was carried to America with the slave trade from the West Coast of Africa (Hammons, 1973). This explains the tracing of groundnut (SEDIAC, 1978) to the Grain Chaco area, which includes the Paraguay and Panama valleys.

2.2.2 Types and Varieties

As noted by Woodroof (1983), it must be pointed out, first and foremost, that any listing of groundnut varieties is incomplete. The various cultivated types of groundnut can be divided into three main varietal groups. These are Virginia, Spanish and Valencia. A fourth one, known as the runner, which is genetically linked to the Virginia type is mainly cultivated for commercial considerations (SEDIAC, 1978):

(i) Virginia:- It is characterized by large pods containing one or two elongated kernels. The constriction of the shell is well marked. The kernels are well separated and without any flattered area;

(ii) Spanish:- It is characterized by small pods, generally containing two round, well separated kernels;

(iii) Valencia:- The pod of this variety is smooth without any constriction. The shell contains three seeds which very often have flat extremities;

(iv) Runner:- The kernels are small and less elongated, often with a flattered part.

Selection of any variety has been found (Woodroof, 1983) to be always based on adaptation to local conditions

(climate and soil), disease resistance and yield. In Nigeria, as in several African countries, the Virginia type is used as a selection basis for the development of improved varieties (IAR, 1989).

2.2.3 Production in Nigeria

There is no doubt that groundnut has played an important role in the crop economy of Nigeria, according to Harkness, (1976). Abalu (1978) reported that the estimated production level ranged between 0.8 to 1.2 million hectares annually. He also indicated that in 1971, over 75% of the area and 85% of the production of groundnuts were accounted for by Kano, Kaduna, Bauchi, Borno, and the "former" Gongola States.

Though Nigeria was the third largest producer of groundnuts in the world after India and China upto 1969, her production trend has since then been on the decline and has been surpassed by countries such as Senegal and United States of America (Abalu, 1978). There was an improvement in production between 1991 and 1993 as indicated by Table 2.1, yet Nigeria's level was surpassed by that of the United States of America (FAO, 1993).

TABLE 2.1: ANNUAL PRODUCTION LEVEL OF GROUNDNUT (kg/ha)

	1979-81	1988	1989	1990	1991	1992	1993
World	994	1212	1161	1141	1151	1185	1190
Africa	728	774	782	800	798	742	766
Asia	1022	1324	1244	1223	1182	1282	1314
N/Cen. America	2253	2425	2428	1997	2434	2491	2115
South America	1511	1881	1532	1742	1952	1854	2020
Nigeria	829	695	813	850	1166	1214	1250
Ghana	1307	1755	1261	1200	670	769	769
Senegal	659	800	1077	1039	831	605	686
Sudan	792	860	449	667	780	778	512
Zambia	640	485	550	519	403	373	622
India	838	1132	1043	938	815	1026	1006
China	1487	1911	1817	1961	2188	2001	2201
U.S.A.	2590	2740	2719	2185	2740	2871	2375

Source: FAO (1993)

2.2.4 World Production

Although groundnut is considered to be predominantly a crop of the tropics, the approximate limits of present commercial production are between latitudes 40°N and 40°S (Gibbons, 1980). According to FAO Trade Statistics (1993), the world production was just over 22.8 million tonnes. Asia remains the largest producer (15.8 million tonnes) followed by Africa (4.7 million tonnes), North and Central America (1.7 million tonnes) and South America (0.6 million tonnes).

Comparison of these production figures with those for 1978 indicates an estimated increase in world production by 2.9 million tonnes. Asia increased its production by 4.9 million tonnes whilst the others experienced a decline in production. Africa's production level decreased by 0.5 million tonnes, North and Central America by 0.28 million tonnes and South America by 0.2 million tonnes. Table 2.1 gives the production levels from 1979 to 1993 (FAO, 1993).

With respect to individual producing countries, India is the largest producer (7.5 million tonnes) followed by China (6.1 million tonnes), Indonesia (0.9 million tonnes), U.S.A. (1.56 million tonnes), Senegal (0.8 million tonnes), Nigeria (0.68 million tonnes) and Sudan (0.4 million tonnes). Comparing with the production estimates of 1978, India increased its production by 1.3 million tonnes and China by 3.3 million tonnes. The U.S.A. experienced a shortfall of 0.24 million tonnes, Senegal by 0.2 million tonnes, Sudan by 0.4 million tonnes and Nigeria by 0.02 million tonnes.

According to Gibbons (1977), yields in the semi-arid tropics are low (around 800-900 kg/ha) compared to yields of approximately 2,500 kg/ha in the developed world, the major constraints being pests, diseases and an unreliable rainfall patterns.

Analysis by Florkowski (1994) has establish that in West Africa, there was a decrease in major producing countries during the 1980s over the 1960s, although output was fairly stable for the region as a whole. Ivory Coast

nearly doubled its output in the 1980s, while in Benin Republic, production increased by 134 percent between the 1960s and 1980s. In Eastern Africa, overall production increased over the period 1960 - 1989. In Sudan, the increase was by 136 percent during the 1970s, but Uganda's average output in the 1980s dropped to 37 percent below its 1960s level. In Central Africa, Zaire's output increased by 89 percent over the three decades. In Southern Africa, the trend was for a decrease in production.

2.2.5 Uses (Domestic and Industrial)

(i) Groundnuts are widely consumed as a nutritious edible nuts contributing protein, carbohydrate, fat, vitamins and minerals to the diet;

(ii) It is a source of high quality edible oil which, because of its ease of refining, outstanding stability and general characteristics, enjoys a price premium over other competitive oils (Harris, 1982);

(iii) It can be boiled, roasted, pounded and grounded to provide snack food, roasted unit confectionary products, soups and stews as well as groundnut butter;

(iv) The oil-cake residue from the groundnut oil extraction is also a valuable protein

source, used as animal feed and also for human consumption when fried (Kulikuli);

(v) Protein concentrates and isolates can be prepared from groundnuts for specific purposes, such as for the production of baby foods. According to Chandrasekhara and Ramana (1968), formula for groudnut floUr, biscuits, and milk from groundnut have been elaborated in India;

(vi) The groundnut flour can be mixed with skimmed milk powder to produce "Arlack" or with millet flour to produce "Ladylack" (Nigeria and Senegal);

(vii) Using protein extracted from the cake, glue can be produced for boards, or a nutritive milieu for the preparation of antibiotics;

(viii) In many countries, the cake is used as an organic amendment for fertilizer;

(ix) The groundnut husks are a major by-product widely used as fuel and to a more limited extent as animal forage;

(x) The shell can be mixed with various products to produce drilling mud;

(xi) The shells, either natural or in compost form may be incorporated in the soil to provide a considerable increase in organic matter content. It also serves to improve the structure and increase the moisture retention of the soil;

(xii) The shells are also used to make agglomerate particle boards after grinding, drying and the addition of gum;

(xiii) According to Francois (1964), the partosan contained in the shells make it possible, after hydrolytic cleavage, to obtain a material known as furfural. Also by using soda or Sulphite, cellulose can also be extracted from the shell;

(xiv) The shells can be grounded and mixed into feed for ruminants to provide roughage (Utley et.al. 1973; Boza et.al., 1969).

2.2.6 Oil Content

The percentage oil content in groundnut, according to TPI (1971) ranges between 38 and 50 percent. In Nigeria, continued search (IAR, 1989) has resulted in the release of several improved varieties as indicated by Table 2.2

TABLE 2.2: GROUNDNUT VARIETIES DEVELOPED IN NIGERIA

Variety	Oil Content (% Dry Basis)	Year of Release
SAMNUT - 1	53 - 55	1960
SAMNUT - 2	53 - 55	1960
SAMNUT - 3	53 - 55	1970
SAMNUT - 4	55 - 65	1970
SAMNUT - 5	51.5	1970
SAMNUT - 6	52.5	1970
SAMNUT - 7	51 - 53	1980
SAMNUT - 8	55 - 60	1980
SAMNUT - 9	50 - 53	1980
SAMNUT - 10	55 - 60	1988
SAMNUT - 11	55 - 60	1988
SAMNUT - 12	51 - 63	1980
SAMNUT - 13	50 - 53	1980
SAMNUT - 14	50 - 52	1988
SAMNUT - 15	50 - 53	1970
SAMNUT - 16	55 - 60	1988
SAMNUT - 17	53 - 55	1988
SAMNUT - 18	53 - 55	1988

Note: SAMNUT = Samaru Groundnut

Source: IAR (1989)

Thus the composition of groundnuts, naturally, vary according to the variety, location and year of production (Holaday and Pearson, 1974), Table 2.3 gives the general composition of the whole groundnut kernel.

TABLE 2.3: GENERAL COMPOSITION OF GROUNDNUT KERNELS

Constituent	Range (%)
Moisture	3.9 - 13.2
Protein	21.0 - 36.4
Lipids (Oils)	35.8 - 54.2
Grude Fiber	1.2 - 4.3
Nitrogen-Free Extract	6.0 - 24.9
Ash	1.8 - 3.1
Reducing Sugars	0.1 - 0.3
Disaccharides	1.9 - 5.2
Starch	1.0 - 5.3
Pentosans	2.2 - 2.7

Source: Feiman et.al. (cited by Woodroof, 1983)

2.2.7 Traditional Processes of Oil Extraction in Developing Countries

Traditional systems of groundnut oil extraction in developing countries involve the use of both manual and small engine-operated machines. Though literature on the traditional processing methods and the equipment used, there-of, is very scanty (Nalumansi and Kaul, 1992). The various techniques applied for each processing operation are summarised in Table 2.4.

TABLE 2.4: SUMMARY OF TRADITIONAL GROUNDNUT-OIL EXTRACTION TECHNIQUES

OPERATION		TYPICAL TRADITIONAL TECHNIQUE	
i.	Removing nuts from shells	Done manually or by hitting with stick	
ii.	Winnowing assistance	Using flat baskets or pans with current	
iii.	Sorting	Done manually	
iv.	Roasting	a.	Done in open pans over direct fire
		b.	By exposing the groundnut under direct solar heat (sun)
v.	Skinning	a.	By rubbing the nuts between two stones
		b.	By rubbing the nuts between a stone and a mat or jute bag.
		c.	By rubbing the nuts between a wood and concrete or a mat.
vi.	Grinding into paste	a.	Done with the assistance of a mortar and pestle manually or with animal power (called Ghani in India).
		b.	Rubbing between flat stones.
vii.	Primary oil Extraction	a.	By exposing the crushed meal to the heat of the sun.
		b.	By compressing the meal in baskets using wooden levers.
		c.	By kneading using a mortar and pestle, either manually (as in Nigeria) or animal power (as in India).
		d.	By adding boiling water to the meal, stirring and scooping the oil off the surface (common in Ghana).
viii.	Secondary oil Extraction	By hand-pressing or kneading on a wooden board (ruling) or a wide flat stone.	
ix.	Frying the rolled meal (minor extraction and oil purification	Frying with oil extracted from vii and viii in a deep pan over ope fire.	

Source: Nalumansi and Kaul (1992); UNIFEM (1987).

Merits of Traditional System

The following merits were reported by Nalumansi and Kaul (1992):

i) The entire operations can be done within a defined enclosure;

ii) The only expenditure is on the purchase of groundnut and firewood (to some extend);

Demerits of Traditional System

The demerits of the traditional system were reported by several authors (Nalumansi and Kaul, 1992; Dunmade, 1991; UNIFEM, 1987) as follows:

i) Operations are done with heavy drudgery;

ii) There is normally no consistency in the degree of roasting which usually takes too long to complete;

iii) The kneading operation, done manually, is strenuous and also takes a longer time, usually requiring more labour;

iv) The oil extraction process is usually left incomplete due to the high drudgery involved;

v) There is normally no proper means of regulating heat for those operations which required heating.

2.2.8 Past Improvements on the Traditional Processing Techniques

Continued research has led to the development of improved processing techniques and/or tools for most of the processing operations used in the traditional system. Table 2.5 gives those operations for which an improved

technique(s) and/or machinery exist (Nalumansi and Kaul, 1992; UNIFEM, 1987).

A line diagram by Nalumansi and Kaul (1992) illustrating the traditional groundnut-oil extraction system, incorporating one of the improved technique (i.e. milling) for grinding the groundnuts into paste is also shown by Figure 2.1.

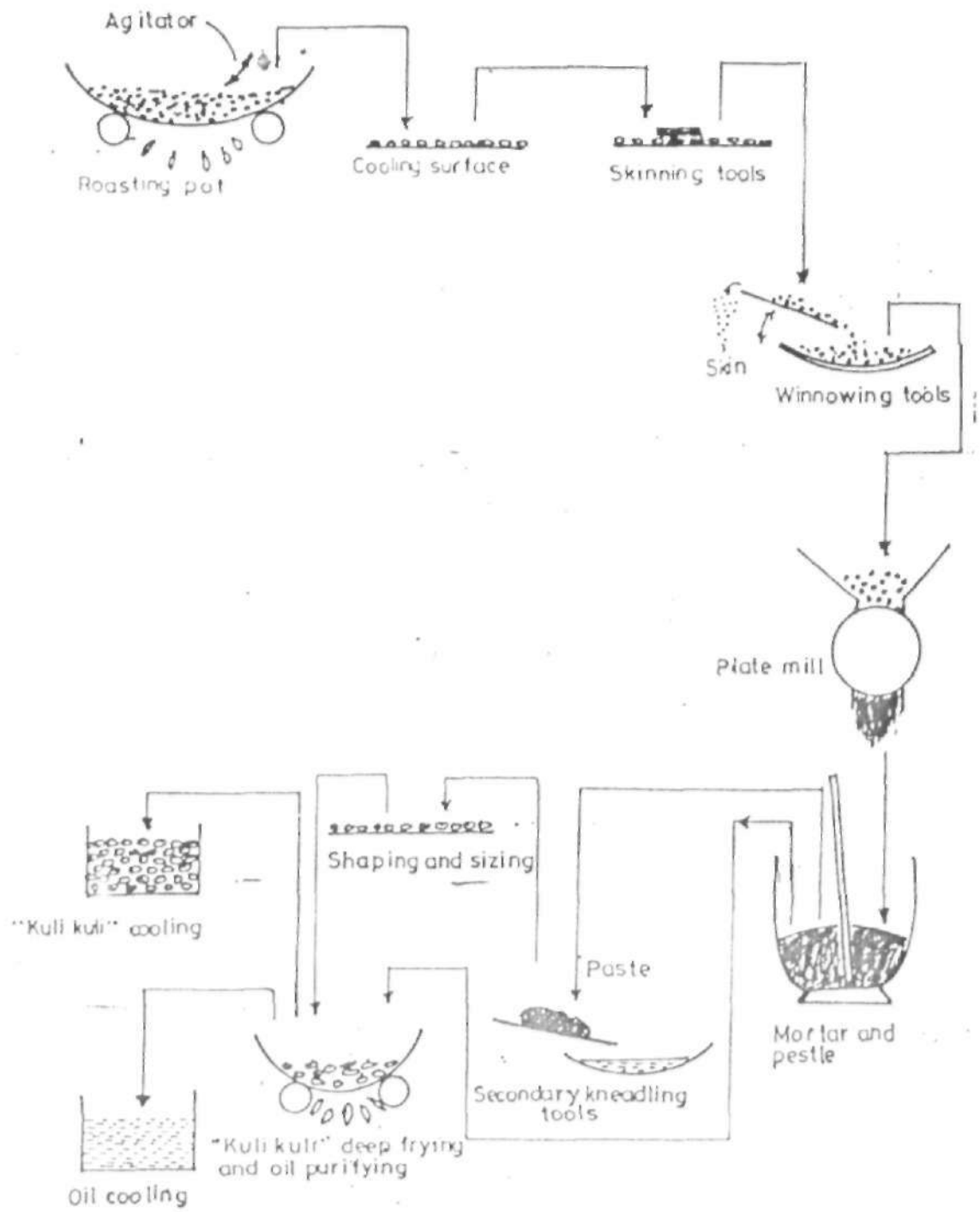


Figure 2.1
Line diagram illustrating the traditional groundnut oil extraction

Source:- Kaul and Nalumansi (1992)

TABLE 2.5: SUMMARY OF VARIOUS EFFORTS TO IMPROVE TRADITIONAL PROCESSING TECHNIQUES

OPERATION	IMPROVED PROCESSING TECHNIQUES	
i. Removing nuts from shells.	By using a mechanical Decorticator.	
ii. Skinning.	By using a metallic sieve and a rubbing plate lined with a wire gauze.	
iii. Grinding into paste.	By the use of a Disc Mill or a Roller Mill.	
iv. Primary extraction of oil.	a.	By the use of a mortar with a modified pestle fitted with a mechanical device to simulate the traditional mode of operation.
	b.	By the use of continuous screw presses or a closed hydraulic press.

Source: Nalumansi and Kaul (1992); UNIFEM (1987).

2.2.9 Attempts Toward Improving the Traditional Primary Oil Extraction Process

(i) Attempts in Nigeria

During their studies on the traditional system of groundnut-oil extraction in Nigeria, Nalumansi and Kaul (1992) identified the kneading operation as the most difficult task as well as the key operation in the entire processing system. They observed that during the kneading operation, others had to assist the person kneading by

holding on the mortar to keep it stable. They assigned the reason for this extra support granted the operator to the fact that the groundnut paste becomes hardened and tougher to turn during the process, hence causing the morter to be unstable. Studies on the motions of the traditional method of kneading led to the development of an improved mechanism (IAR Modified Pestle) by Nalumansi and Kaul (1992).

A model hydraulic press for oil extraction was also developed by Eke et.al. (1988). They reported that the machine could extract oil from several oil seeds, even though it was basically designed and constructed for extracting-oil from beniseed. Experimental test results on the model hydraulic press showed some performance constraints. Eke et.al. (1988) discovered that the hydraulic jack component of the press could not generate the expected high pressure required for complete oil extraction from the meal of the beniseed. They also found out that oil was not completely pressed out of the meal when the press cylinder was filled up. They also reported the presence of suspended materials in the extracted oil which had to be sedimented and the oil decanted.

(ii) Attempts in Burkina Faso

In Burkina Faso, a screw press was introduced into a "United States save the Children" Federation project with a view to improving the traditional method of groundnut oil processing. Although the press eliminated the operation of skimming oil from the surface, the small round plate that

fits into the cylinder to press the nut, regularly stuck at an angle inside the cylinder, because of uneven pressure caused either by inconsistent chopping of the nuts or by the fact that they were inadequately pounded (Corbett, 1981). The press large enough to take about two kilograms of nuts at a time, could not produce enough oil to make it worth the time and effort. By virtue of it being heavy and hard to clean, the screw press totally became unpopular (UNIFEM, 1987).

2.2.10 Advanced Technologies for Oil Extraction

Various advanced techniques have been used in the extraction of oil from oil-bearing seeds. Table 2.6 gives a summary of some of these techniques.

TABLE 2.6 SUMMARY OF ADVANCE PROCESSING TECHNIQUES

OPERATION	ADVANCE PROCESSING TECHNIQUE	
i. Winnowing	a.	Floatation of the kernel in brine.
	b.	By use of moving inclined belts.
ii. Sorting(cleaning)	a.	Using rotary sieves to extract dirt.
	b.	Using magnets to extract metallic particles.
	c.	Use of air-jets to extract husks and dust.
	d.	Use of photoelectric-cell beams set at correct kernel colour to distinguish mould infested kernels (separated by jets of air).
iii. Roasting	This is done under controlled or regulated conditions of 90°C for about 20 minutes and with about 8 or 10	

percent moisture content. Steam jackets are often employed.

iv. Skinning — This is done by Blanching. There are four methods:

(a) **Dry Blanching**

The shelled groundnuts are heated at 140°C for 25 minutes. The skins crack, and the groundnuts are then cooled and afterwards passed between brushes or ribbed rollers which remove the skins.

(b) **Hot Water Blanching**

In this process, the kernels are rolled over fine stationary steel blades which cut the skin longitudinally on both sides. The kernels are sprayed with hot water to loosen the skins which are then removed by passing the kernels between a rubber pad and an oscillating cloth-covered pad. Finally, the kernels are dried under a current of hot air (45 °C), over a period of six hours.

(c) Sodium Hydroxide Blanching
Here, the shelled nuts are immersed for 8 seconds in a one percent solutions of sodium hydroxide and then rapidly dipped into a one percent solution of hydrochloric acid to avoid the appearance of any red stains on the kernel. The skins are rinsed off with water and the kernels are dried.

(d) Hydrogen Peroxide Blanching
In this method, the nuts are immersed in the hydrogen peroxides for a period of 30 to 60 seconds. The catalase contained in the groundnut decomposes the peroxide into water and oxygen which causes the skin to swell away from the kernel, providing easy removal. The whole operation is said to take between 10 and 15 minutes to complete.

v. Extraction

(a) Continuous solvent Extraction method
This is a method (Counterflow) used to remove oil (about o10 percent) contained in the ground "flakes" after pressing. Solvents most frequently used are B-spirit, Hotzone and trichloroethylene.

(b) Aqueous Extraction Method
In this method, oil is extracted from comminuted oil seeds followed by centrifugal separation which divided the aqueous extract into oil, solid and an aqueous phase. For groundnuts, the recovery of oil was 89 percent for the concentrate procedure, whilst it is 86 percent for the isolate procedure (Cater, 1973)

Source: SEDIAC (1978); Cater et.al. (1973); Todey (1971).

2.2.11 Extraction of Oil from Groundnut by Centrifugal Action

The groundnut kernel is known to be composed of approximately equal weights of fatty and non-fatty constituents, the relative amount of each depending upon variety and maturity. According to Asiedu (1994), most of

the fatty constituents are found in the cotyledons which make up the bulk of the kernel or seed. He also indicated that all cells of the groundnut embryo contains oil in an extremely fine emulsion. Thus when kernels are bruised or broken, a sufficient number of cells are injured. As a result, tiny drops of 'free' oil ooze out and collect on the surface of the kernels (Asiedu, 1994). Hence the grinding task of the groundnut into paste, according to Carr (1989), is to remove from each microscopic oil cell within each tiny seed, the maximum quantity of oil present without chemically altering the oil or protein quality.

Since the groundnut paste, as an emulsion (Asiedu, 1994), consist of oil (viscous liquid) in which particles of non-fats are suspended, application of the centrifuge principle allows for the separation of the small solid particles in the viscous liquid. This is attributed to the rotational motion undergone by the various particles within the emulsion. The collection of solid particles then form a new structure which finally results in the formation of groundnut cake. This defatting of groundnut result in higher concentration of protein content from 43.8% to 68.6% (Ghuman et.al., 1990).

The dislodging of the oil molecules in the emulsion (paste) is enhance by the addition of hot water during the kneading process. The heat provided by the relatively hot water molecules to the emulsion, according to Carr (1989) will result in the following actions:

i) the complete breakdown of the oil cells;

ii) coagulation of the proteins to facilitate the oil and cake separation;

iii) insolubilization of the phospholipids;

iv) increased fluidity of the oil at higher temperature;

v) inactivation of enzymes.

The hot water molecules approach the oil cells and transfer the heat energy they possess to the unstable oil molecules being held in their ruptured cells. Immediately these oil molecules break away from the bonds holding them, the water molecules within the surroundings quickly fill up the empty oil cells, encouraging the coagulation of the proteins in the defatted groundnut (cake) which forms clots in the separated oil. As the clots are formed, most of the free oil molecules are entrapped inside them.

The object of grinding the roasted groundnut into paste, as corroborated by Williams (1966), is to fasicilate the separation of the oil from its containing cellular tissue. Thus the form of grinding regarded as most suitable varies to a certain extent, according to the method of production employed. Hence for the application of mechanical pressure, the walls of the cells in which the oil is enclosed must be definitely destroyed, as far as

possible. This allows for the promotion of ease and economy in expressing the oil. As such, the finest possible grinding is desirable (Williams, 1966), meaning that the average particle size must lie within the microscopic range (i.e. < 0.07 mm).

2.2.12 International Trade in Groundnut Oil

World exports of groundnut oil increased sharply between 1960 and 1968, reaching 510000 MT, but the trade decreased in the late 1960s. Africa exports dominated the world oil market and the varying volume of groundnut-oil on that market resulted from the variable supply coming from Nigeria and Senegal (Florkowski, 1994). Senegal was the largest exporter in the 1960s, followed by Nigeria and Argentina.

During the 1970s, the most significant change was a steady decline of Nigerian oil shipments. Towards the end of the decade, Nigeria became a net importer of groundnut oil (Florkowski, 1994). Senegal remained the largest groundnut oil exporter, but at highly variable rates, during the 1970s. In the 1980c export from Senegal, Argentina and Brazil decreased, and the Sudan began to export significant quantities of groundnut oil. Major buyers include members of the European Community, purchasing from Africa and Argentina (Florkowski, 1994).

2.2.13 International Trade in Groundnut Cake and Meal

According to Florkowski (1994), the trade in groundnut cake and meal followed a different pattern from the trade in shelled nuts or oil. European countries were the major buyers of meal in the first half of the 1960s; Japan and the Soviet Union also pur ased significant quantities of cake and meal.

The international trade decreased during the second half of the 1970s and the presence of aflatoxin in the cake exported from Senegal may have contributed to a decrease in exports to Europe (Florkowski, 1994). The Sudan emerged as a large cake and meal supplier towards the end of the decade. In the 1980s, the trade continued at the 1970s level, according to the geographical pattern established in earlier decades. The exception was the year 1985, when exports reached a record low level of 385000 MT (Florkowski, 1994). Europe remains the primary destination for cake and meal exports.

2.3.0 WORK PHYSIOLOGY AND MEASUREMENTS

Two forms of work can be described. These are static work and dynamic work. To the physicist, static work is contradiction in terms - since by definition, "work is done when a force move its point of application". The physiologist see nothing wrong with the idea of static work - since the muscle is consuming energy despite the fact that it is not creating movement (Pheasant, 1991).

2.3.1 Bases for Human Activity Performance

According to McCormick (1976), the abilities of people to perform various types of activities depend essentially on the physical structure of the body (i.e. the skeleton, the skeletal muscles. the nervous system and the metabolic processes).

He further asserted that the basic structure of the body is the skeleton which consists of 206 bones. Some of these bone structures serve primarily, the purpose of housing and protecting essential organs of the body, such as the brain, heart, lungs and other internal organs. The other bones, referred to as skeletal bones, are connected at body joints and are principally used in physical activities. These include the hinge joints (e.g. fingers and kness), pivot joints (e.g. elbow) as well as the ball and socket joints (e.g. shoulder and hip). Vertebrae joints of the spine make possible, the collective and considerable rotation and forward bending of the body.

i. The Skeletal Muscle System

The skeletal muscle consist of bundles of muscle fibres which serve to convert chemical energy into mechanical work. The two ends of each muscle blend into tendons which are, in turn, connected to different skeletal bones such that when the muscles are activated, they apply some form of mechanical leverage on the body (Cooper et.al., 1982).

ii. Muscle Action

A muscle may be considered, functionally, as an assemblage of groups of muscle fibre innervated by a single motor ner fibre (Marcus, 1953). It is these groups, known as motor units, which constitute the smallest physiological components of muscle action.

Upon the contraction of a muscle, either to effect a greater speed of movement or to lift a heavier load, there is an increase in the overall activity of the muscles primarily involved (Knowlton et.al., 1951; Lundervold, 1951). This increase, according to Adrian and Brouk (1929), and Seyffarth (1940), is accomplished by raising the rate of contraction of each motor unit and by calling into play more motor units.

Marcus (1953) postulated that the length of time that a person can maintain in a given muscular performance, obviously depends on a large number of different factors; amongst which are - the structure of the muscles involved and the practice in the task.

In general, static muscular effort can be maintained for much shorter periods than phasic movements. In phasic movements under given set of conditions, the inability to maintain a given performance occurs earlier if a load being lifted at a constant rate is increased or if a constant load is lifted at increasing rate (Knowlton et.al., 1951). By virtue of their action, muscles of the body produce stresses on many body parts other than the bones, such as the skin, organs and connective tissues (Cooper et.al.., 1982). The importance of the body musculature, as indicated by Schottelius and Schottelius (1978), is readily appreciated when one learns that it constitutes 43 percent of the body weight of an adult mar and from Pheasant (1991), between 25 and 35 percent in an adult woman. Thus the body musculature contains more than one-third of all

the proteins, and contributes about one-half of the metabolic activity of the resting body (Pheasant, 1991).

2.3.2 Energy Source for Muscle Work

In simple terms, the human body is an engine that provides muscle power to perform work, and like any engine, it must operate within the limits set by the laws of physics (Miller and Horvath, 1981). The body uses oxygen which enters through the lungs to burn fuel supplied t' ough the digestive system to produce energy which is then converted into kinetic and chemical energies, required for sustaining body functions. This conversion, which occurs within the cells of the body is often referred to as metabolism.

(i) Muscle Metabolism

The contraction of a muscle requires energy, the basic source of which is glycogen. The conversion of glycogen into energy consists of a chemical reaction that ends in the production of lactic acid which needs to be dissipated by being broken down into carbon dioxide and water.

The first stage of the breakdown (ie. from glycogen to lactic acid) does not require oxygen, and is said to be Anaerobic. The second stage (i.e. breakdown from lactic acid into carbon dioxide and water) is said to be Aerobic since it requires oxygen.

At the start of any physical activity, the muscles can utilize the glycogen which is already available even

though the amount present as well as that of glucose is small (McCormick, 1976). If the activity is continued, then the body needs to replenish these nutrients from the blood, along with a supply of oxygen, to help in complete breakdown of the accumulated lactic acid. However, if the amount of oxygen delivered to the muscles fails to conform to the level of physical activity, the lactic acid will accumulate in the blood. Consequently, the muscles will cease to respond.

Foodstuffs involved in resynthesis process are carbohydrates, fats and proteins. The main sources of energy, on the other hand, are carbohydrates and fats with protein being essential for growth and maintenance of the body (Haggard and Greenberg, 1977). Also, two high energy compounds that play important roles in supplying energy for muscle contraction are Adenosine Tri-phosphate (ATP) and Creatine Phosphate (Morehouse, et.al., 1959). According to Miller and Hovarth (1981), the ATP utilizes the energy available in food to synthesize high-energy chemical bonds from which chemical energy is released to fuel the muscle contraction. Pheasant (1991) has pointed out that there is only enough ATP stored in a muscle to fuel contraction for about two seconds, but as the ATP is broken down, it is constantly being reformed in coupled chemical reaction involving phosphor-creatine (creatine phosphate). There is enough phosphocreatine stor in a muscle to keep it working at full capacity for about ten seconds at the most. When these reserves have been exhausted, energy for the

resynthesis of ATP must come from other, less direct sources (Pheasant, 1991). Figure 2.2 shows the distribution of food energy within the body.

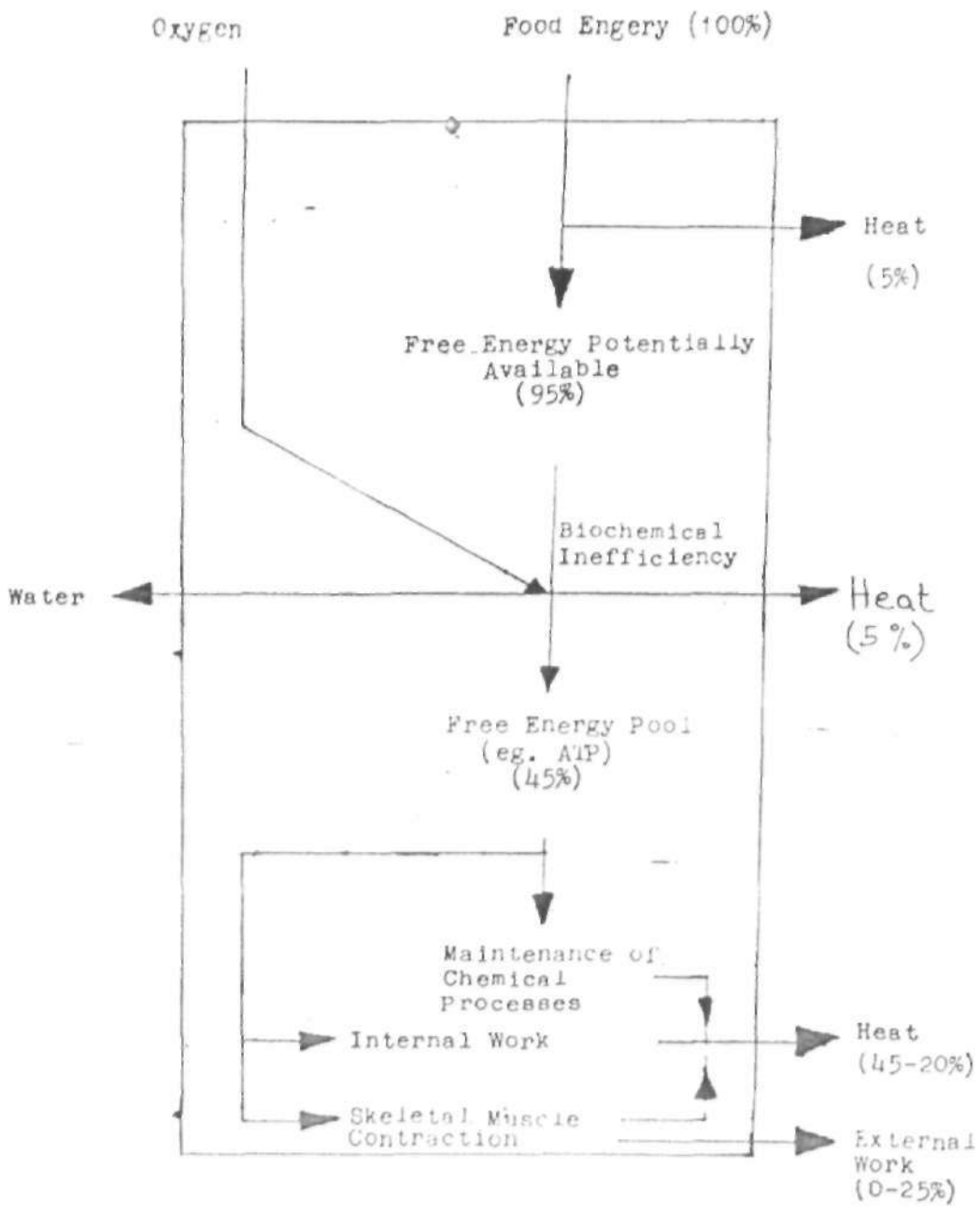


Figure 2.2: Distribution of Food Energy Within the Body.

Source: Miller and Horvath (1981).

(ii) Basal Metabolism

This is the minimum energy required for the sustenance of life. Thus the minimum energy conversion rate (i.e. energy expenditure of a resting person), which is also referred to as the Basal Metabolic RAte (BMR), can be estimated for both sexes using the following formulas, quoted by Miller and Hovarth (1981) and credited to the International Commission on Radiological Protection (1975).

for males:

$$BMR = 66.5 + 13.8\ (\text{weight}) + 5.0\ (\text{height}) - 6.8\ (\text{age}) \quad (1)$$

for females:

$$BMR = 66.5 + 9.6\ (\text{wight}) + 1.8\ (\text{height}) - 4.7\ (\text{age}) \quad (2)$$

The energy is calculated in kilocalories per 24 hours; wight in kilogram; height in centimentres and age in years.

2.3.3 Capacity for Work Performance

The capacity for physical labour varies from person to person. Some of the reasons for these are - the level of physical fitness; nutritional status; age; sex and health. In order to establish limits for physical workload for a particular task, then the maximal energy requirement on the physical worklands for a number of different individuals must be compared (Miller and Horvath, 1981). Thus the best way to measure work capacity is by determining the maximum amount of oxygen used.

(i) Effect of Age and Sex on Work Capacity

The efficiency with which physical work is performed as well as the ability to sustain a high workrate depend greatly on the individual's state of health and nutritional status. Spur et.al. (1978) suggested that malnutrition in young children may result in depressed work capacities as adults.

Whilst aerobic work capacity peaks in the late teen years, work capacity rather decreases gradually throughout life following the peak in the early years (Miller and Hovarth, 1981). Astrand (1969) also found that the average woman has a lower work capacity than the average man. For the same task, a woman would operate at a higher relative workload. At the age of 18 years, her maximal aerobic capacity might be 2.6 L/min (876 W) and at age 6[illegible] years, it is about 1.8 L/min (606 W). Astrand (196[illegible] further realised that the relative workloads of the woman on a heavy task would be 14 percent at age 18 years, and 20 percent at age 60 years. He then concluded that if a woman selected for a heavy task is to be matched with the man in terms of height, weight and physical fitness; as well as in terms of aerobic capacity, the woman would be at no disadvantage in comparison to the man. Michael at.al. (1961) have shown that a person of average physical fitness can work continuously (50 minutes each hour) for 8 hours at 35 percent m[illegible].mum oxygen without producing undue fatigue.

Per - Olof (1954) has also argued that no proved reason exist to show why women could not utilize 50 percent

of their capacity in manual work. Their aerobic capacity has been found to be 25 to 30 percent lower than that of males. Consequently, the heaviest work to be permitted for women should be a corresponding percentage lower despite the fact that she could push herself to the same rate of exhaustion as the male.

(ii) Working Limits of Local Muscle Groups

Although the capacity of an activity might be within reasonable limits, it is possible for individual muscle groups to be worn out with excessive use. If the rate of contraction of a muscle or muscle group is low enough, it can function almost indefinitely. But at higher rate, it can become completely fatigued and cease to function at all (McCormick, 1976). Hence the outer bounds of the ability of an individual to continue an activity are prescribed by the total energy expended and/or the recovery rates of individual muscles or muscle groups. These possible constraints, in effect, should dictate the workrate that should not be exceeded for continuous effectiveness of the individual performing the activity.

(iii) Work Capacity and Rest

Provided some ceiling for work (such as 4 or 5 Kcal/min) is accepted as a desirable upper limit for average energy expenditure, then it could be inferred that any activity with energy exceeding this limit requires a rest. In this wise, Murrel (1965) provided a formula for

the estimation of the total amount of rest (scheduled or not scheduled) required for any given work activity, depending on its average capacity. This formula (with different notations) is given as follows:

$$R = \frac{T\,(K - S)}{K - 1.5} \qquad (3)$$

where:

R = rest required (minutes)

T = total working time (minutes)

K = average kcal/min of work

S = kcal/min adopted as standard

The value (1.5) in the denominator is an approximation of the resting level, in kcal/min.

Alternatively, if S is given a value of 4 kcal/min, and R is to be estimated for a one hour period (i.e. T = 60 minutes) equation (3) then reduces to the follows:

$$R = \frac{60\,(K - 4)}{(K - 1.5)} \qquad (4)$$

Because of other considerations, such as the more psychological factors of boredom and shift in attention, some rest must be provided for virtually any kind of continuous work, even though its physiological costs are nominal (McCormick, 1976). Table 2.7 gives the scaling of work, using physiological indices which could be valuable in assessing the need for work modification or adequacy of rest periods proposed by Christensen (1976). According to Pheasant (1991), this scaling of work is applicable to an averagely fit young man in his early twenties.

Table 2.7: SCALING OF WORK BY PHYSIOLOGICAL INDICES

PHYSIOLOGICAL VARIABLES	PHYSIOLOGICAL WORKLOAD					
	Very Light (<)	Light	Moderately Heavy	Heavy	Very Heavy	Extremely Heavy (>)
Oxygen Uptake (L/min)	0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5
Energy Expenditure (Kcal/min)	2.5	2.5-5.0	5.0-7.5	7.5-10.0	10.0-12.5	12.5
Heartrate (Beats/min)		75-100	100-125	125-150	150-175	175
Rectal Temperature (oC)			37.5-38.0	38.0-38.5	38.5-39.0	39
Sweating Rate (ml/min) for 8 - hour work day			200-400	400-600	600-800	800

Source: Pheasant (1991); Christensen (1976)

2.4.0 ENERGY EXPENDITURE STUDIES IN AGRICULTURAL TASKS

One of the problems of "scientific management" or "work rationalization", whether it be of human, cow or horse, is to determine, for an animal of given productive capacity, the workload or level for maximal long-range efficiency.

Energy demand with respect to several agricultural task has been investigated by numerous researchers with a view toward improving the task and/or machines for

increased performance and task efficiency. Vos (1973), in a study in which he used a task of picking up metal tags which are placed in a standard pattern on the floor (to illustrate agricultural tasks carried out at/or near ground level), found that a kneeling posture with hand support and a squatting posture required less energy than other postures (i.e. kneeling with no hand support; bending with no arm support; and bending with arm supported by thigh). He, however, clarified that the kneeling postre precludes the use of one hand which might cause knee discomfort over a period of time. In an earlier study, Vos (1966) investigated human effort involved in the stacking of bales of straw on a standing, as well as on a jerking and rolling wagon. He found that the total energy expenditure ranged from 4.5 kcal/min to an amount greater than 11.0 kcal/min, with the heartrate also ranging from 88 beats/min to an amount greater than 130 beats/min. Considering Lehman criterion, it was suggested that workload should not exceed an average 5.5 bales/min (120 kg/min) on a stationary trailer and 4.0 bales/min on a moving one.

The effect of vibration of a back-mounted power equipment, as in sprayers, using a vibration exciter was investigated by Gupta and Pathak (1981). They discovered that operations at high speeds with vibrations in transverse direction were less strenuous. Singh et.al. (1973), n the other hand, evaluated the displacement and velocity of different body parts due to vibrations from a back-mounted power sprayer and concluded that various parts

of the body are subjected to different displacements and velocities.

In a comparative studies of four methods of winnowing cereal grains to assess winnowing performance as well as energy demand on operators, Sutton (1974) showed that a pedal driven winnower with basic screen separation and horizontal air inflow was better when all the performance indices are taken into consideration.

Nwuba (1981), in his study on human energy demand of agricultural hand tools used in different tasks, observed that tools with long handles have the least energy requirement. Nwuba and Kaul (1986) also discovered that usage of handtools of different handle lengths, but same blade lengths, result in different operational postures. It was found that the spinal muscle force and the lumbosacral joint reaction, while using the traditional hoe modified with a 150 cm long handle were reduced to between 20 and 38 percent of those with the short handles. In their attempt to improve the traditional shadoof irrigation method through ergonomic studies, Nwuba and Kaul (1985) succeeded in reducing the energy expenditure required to operate the system from 100 watts to 71 watts, a level at which a farmer could work for prolonged periods without a need for rest.

Curfs (1974) studied the physiological demands of walking tractors at the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria, and concluded that the tractors were unsuitable for use on

Nigerian soils, because they cause an increase in the pulse rate of operator by more than 30 beats min (which was recommended as tolerance limit).

Ali (1986) conducted a comparative ergonomic studies of male and female operators on some selected farm taks in which he found that female subjects, invariably, recorded higher energy expenditure per unit output for all tasks, with the energy expenditure difference ranging from 10 percent for weeding to 44 percent for ridging. He found that in ridging operation, the energy required to dig up and invert one cubic metre of soil was 36.6 kJ for male groups, and 64.8 kJ for the females. Trials designed to study the effect of calculated rest intervals showed that; for all cases, output was increased whilst energy expenditure reduced under a "controlled schedule" compared to a "Normal Schedule" (Ali, 1986). With respect to effect of environment on energy expenditure, Ali 1986) realised that energy expenditure difference between extreme weather conditions ranged from 2.5 percent for ridging to 13 percent for pounding operations.

Generally, in discussing energy expenditures over the period of the conventional working day, Lehmann (1958) estimated that the maximum energy output a normal man can afford in the long run is about 4800 kcal/day. Subtracting his estimate of basal and leisure requirements of 2300 kcal/day leaves a maximum of 2500 kcal/day available for the working day, even though he proposed 200 kcal/day as a more normal load. This average came out to be about 5

kcal/min to 4.2 kcal/min. On the other hand, Endholm (1967) suggested that the 200 kcal/day (4.2 kcal/min) should be considered as maximum, and that levels should, preferably, be kept somewhat below this limit.

2.5.0 MEASUREMENT OF ENERGY EXPENDITURE

Physiological demands of work are frequently measured by heartrate and oxygen consumption. These two measures are rather closely correlated with each other across varying levels of general dynamic muscular work. On the other hand, Burger (1969) stated that neither of the two is a very sensitive index of static muscular work, "local" dynamic muscular work (that of specific muscles or muscle groups), mortal work, nor mental work. Other physiological indices are also employed in the energy expenditure measurement. These include pulmonary ventilation, sweat a rate and rectal temperature.

According to Karpovich et.al. (1971), one method which had been used, but later found to be often not feasible, especially for tasks of short duration, is the Direct Calorimetry. In this method, a subject is placed in a special chamber fitted with a water circulatory system around it. Heat liberated from the subject is absorbed by the circulating water, and knowing the amount of water as well as its temperatures when entering and leaving the system, the total heat liberated by the subject can be calculated.

2.5.1 Oxygen Consumption

Oxygen consumption is determined by considering the volume of air breathed in by a subject and the reduction in the oxygen content of the air breathed out. There are two common methods which can be used. These are the closed-circuit method and the open-circuit method.

In the closed-circuit method, a spirometer is used with two one-way valves. One valve allows the inhale gases out while the other valve allows the exhale gasses in, via a carbon dioxide absorbent system. The subject inhales the oxygen from the spirometer and the gas exhaled passes through the absorbent system into the spirometer. The amount of oxygen consumed is then obtained by finding the difference between the volume of oxygen at the beginning and at the end of the activity (Karpovick and Sinning, 1971).

In the open-circuit method, the subject is made to breath in atmospheric air and the gases exhaled collected in a special air-tight bag known as Douglas Bag. This accurately determine the volume of the exhaled gas. The composition of a sample of the gas is then analysed using an instrument called Analyser. Since the composition of atmospheric air is constant, containing 20.93% oxygen, 0.03% carbon dioxide and 79.04% nitrogen; and since the amount of air is known, then the amount of oxygen consumed and that of carbon dioxide given out can easily be calculated (Karpovick and Sinning, 1971).

Thus for any particular task, the total oxygen required is given by the oxygen consumed during the activity plus the recovery or debt oxygen minus that used in resting, i.e.:

$$\text{NET COST OF OXYGEN PER MINUTE} = \frac{O_2\ (\text{work}) + O_2\ (\text{recovery}) - O_2\ (\text{resting})}{\text{Duration of work (minute)}} \quad (5)$$

According to Karpovick and Sinning (1971), the caloric equivalent of one litre of oxygen varies from 4.686 calories to 5.04 calories, depending on foodstuff type. Therefore, the energy expended can be obtained from this relation or from previously prepared calibration graphs. Relationship between the amount of oxygen consumed and the energy expended is linear. For most practical purposes, according to Pheasant (1991):

$$\text{ENERGY EXPENDITURE (kcal/min)} = 5 \times \text{OXYGEN CONSUMPTION (L/min)} \quad (6)$$

2.5.2 Heart Rate

Advantages of using heartrate as an index of energy expenditure has been outlined by many researchers (Le Blanc, 1957; Datta et.al., 1969; Christenesen, 1976), but according to McCormick (1976), though heartrate is reasonably indicative of the effects of heat stress and emotional stress, it is also related to individual factors (constitution, physical condition, sex, etc.) and is therefore less suitable as an absolute index of the load imposed by various types of work than oxygen consumption.

Since heartrate and oxygen consumption have their limitations as measures of physiological demands on an across-the-board-basis, Burger (1969) has argued for the use of an index of circulating load as something of a combined index of the load of different organic systems. An approximation of this is the product of heartrate, mean blood pressure and stroke volume.

A somewhat related measure based on heartrate is what Davies (1968) referred to as the Pulse Deficit (P.D.). This reflects the deficit in cardiac output in the early stages of an exercise and is, thus an indication of the level of anaerobic metabolism. Operationally, the P.D. is calculated by taking the heartrate for the fifth minute as reference and calculating the area bounded by the pulse-time curve for the first four minutes of exercise.

However, Shephard (1970) has suggested that the pulse rate usually continues to rise during the second five minutes of exercise and so a deficit measure based on the second five minutes would have more significance as a measure of the intensity of exercise

Another measure based on heartrate is the Heartrate Recovery Curve as used by Brouha (1960). This is a curve of the heartrate measured at certain intervals after work (such as 1, 2 and 3 minutes).

Equipments used for the evaluation of heartrate are less obstructive with minimal work interference compared to those for oxygen consumption. Heartrate is measured by palpation, through the use of stethoscope, telemetry systems or by the use of cardio-tachometers. The telemetry system is a simple method in which electronic devices incorporating electrodes are mounted on a subject's body to detect electrical impulses of the vascular muscles. Amplified signals of these impulse are then tr. smitted to a remotely recording gear in a fashion similar to the transmission of sound waves to radio sets.

When a subject begins work from a "rest" condition, the heartrate increases immediately and then reaches an equilibrium with the task within a relatively short time. For light to moderate tasks, equilibrium is reached in 3 minutes or less (Suggs and Splinter, 1958; Karpovick and Sinning, 1971). Datta et.al.(1969) obtained a highly significant relationship between energy and heartrate with a correlation constant of 0.88 which made heartrate to give an acceptable estimate of energy expenditure.

Since there is a linear relationship between oxygen consumption and energy expenditure, then it can be fairly concluded that a linear relationship exists between heartrate and energy expenditure (Karpovick and Sinning, 1971). Studies have shown that this linear relationship exists until maximum value of heartrate is attained, after which it remains constant for same environmental conditions. However, for a varying environment, heartrate reflects total strain on the body rather than energy expenditure. In general terms, the more strenuous the work activity, the longer it takes the heart to settle down to its pre-work level.

In many respect, according to Pheasant (1991), heartrate is a better index of the overall physiological demands of work than energy expenditure, and it has the additional advantage of being very much easier to measure in the field. According to andjean (1988), the heartrate during continuous work should not be more than 35 beats/min

and 40 beats/min higher than the resting level for women and men respectively.

2.5.3 Pulmonary Ventilation

This physiological index is used for indirect measurement of energy expenditure. It can be readily measured using a gasmeter, and the corresponding energy expenditure values could be obtained from tables, graphs or by equations.

Ford et.al. (1959) presented a method for determining energy expenditure from pulmonary ventilation, and using it under field situations, they obtained a regression equation which was similar for all age groups. Their studies showed that correlation between pulmonary ventilation and energy expenditure is high. Hence the relationship is linear and can be represented by a linear equation. There is also a linear relationship between ventilation rate and rate of oxygen consumption. Therefore, ventilation (breathing) rate can be used to appraise an activity of normal load (Karpovick and Sinning, 1971).

Datta and Ramanathan (1969), using nine volunteers to perform different tasks obtained data on pulmonary ventilation and energy expenditure which shows a highly significant regression relations with a correlation constant of 0.9.

2.5.4 Sweat Rate and Rectal Temperature

These two indices can also be used as indicators of workload, but their use is limited by their failure to reflect sudden changes in workload. Christensen (1976) explained this limitation as partly due to the relatively large heat capacity of the human body. But Yamazaki et.al. (1994) have now established that for the phase immediately after the beginning of an exercise, the sweating rate increases before there is a rise in body temperature. They ascribed this to non-thermal inputs to the sweating centre.

Under adverse conditions, sweat rate reflects total physiological strain on a subject. Sakakibara et.al. (1989) demonstrated that palmer sweating was increased by noise and vibration. Saito et.al. (1990) suggested that the response of sympathetic nerve activity leading to foot voler skin activity during isometric hand gripping contain mainly sudomotor activity which might be influenced by central command and input from peripheral mechonorecptors. Thus it appears that the sweating on palms and soles is caused by emotional, mental or sensory stimulation (Kuno, 1956; Sakakibara et.al. 1989).

Rectal or Oral temperatures, according to McCormick (1976) are measures of the body core temperatures as a result of the direct effect of heat stress on a subject.

Sweat rate is determined by measuring fluid intake during the span of a shift, and weighing the subject at the beginning and end of the shift (Christensen, 1976). This index appears to be backed by Yamazaki et.al. (1994) who

suggested that palmer sweating is influenced by changes in different inputs from mechanoreceptors in muscles, tendons and skin with the change of work rate.

2.6.0 MUSCULAR WORK MEASUREMENT

The measurement of muscular work, generally, involves the evaluation of the physical work performed by a subject.

A direct method of measurement involves the computation of forces exerted by a subject in performing a particular task multiplied by distances of the respective forces (Suggs et.al., 1958; Barham, 1978). But according to De Looze et.al. (1994), in repetitive lifting, a difficulty arises that stems from the fact that this activity involves significant amounts of both positive (traditionally defined as the work generated by shortening muscles) and negative (the work done on active muscles that are stretched) mechanical work. In addition to the positive work that is generated to raise the load, significant positive and negative work are involved in raising and lowering the subject's own body mass. Thus for repetitive lifting or lowering, separated activities of positive and negative work cannot be studied. This is because they cannot be executed repetitively due to the required up and down motions of the lifter's body in each movement cycle (De Looze et.al., 1994). As a result of the difficulty in the evaluation of forc acting with their respective distances during work, other ways and methods had been devised for work measurement.

Devices commonly used include Bicycle Ergometers and Treadmill. There are different forms of ergometers, and selection depends on the muscle group to be evaluated.

2.6.1 Bicycle Ergometer

Bicycle Ergometers appear in different forms and are categorised by the type of resistance they provide (viz springs, weights, friction or magnet pull).

A common type of Bicycle Ergometer is the friction type. In this type, one of the bicycle's two wheels (normally the front wheel) is transformed into a flywheel. A friction belt around the flywheel is attached, at one end, to a weight hanger, and the other end to a scale. When an operator's feet are off the pedals and the flywheel remains stationary, the reading on the scale gives the weight of the hanger. However, when the ergometer is being pedalled, the reading on the scale decreases.

Difference between the applied weight and the final reading on the scale gives a reflection of the frictional resistance (F) on the flywheel. The work done (W) after a number of revolutions (N) of the flywheel is given by the following equations (Karpovick and Sinning, 1971):

$$W = 2\pi r NF \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

or

$$W = Fr\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

where;

r = radius of the flywheel (metres)

θ = angle moved by flywheel (radian).

The Bicycle Ergometer is still being used for physiological studies and also for fitness test. It has been recommended that the pedalling rate be normally established in the range of 50 to 60 pedal-revolution per minute, which is the most efficient for submaximal or maximal effort (Mellorowicz, 1966; Banister and Jackson, 1967; Hermansen and Saltin, 1969).

2.6.2 Hand Ergometer

This is used for evaluating external work of the upper limbs. It consists of a bracket on which a flywheel is mounted. This bracket is also used to attach the assembly to a rigid support. A friction belt is then wound partially around the flywheels periphery. A weight is then attached to one end of the belt whilst a spring scale is attached to the other. The flywheel is provided with a crank handle to effect rotation of the flywheel about the bushing fixed on the bracket.

The difference between the applied weight and the scale reading during the cranking gives the frictional force (F) imposed on the flywheel. The work performed (W) is calculated from the following equations:

$$W = 2\pi r NF \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

or

$$W = Fr\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

where the parameters r, θ and N are defined in section 2.6.1.

2.6.3 Treadmill

This consists, essentially of a belt conveyor or driven by a motor on rollers. This belt is usually inclined at an angle to allow for the quantification of work involved in such tasks as walking or running for a specified period of time at a given belt speed.

When the treadmill is in operation, a subject runs or walks on the moving inclined belt, thereby doing work against gravity. The force of gravity is given by the body's weight, and the speed of movement is determined by the speed of the belt. Since there is no movement in the horizontal direction, the horizontal work done is zero.

If a subject of weight (W) walks or runs on a belt moving at a velocity (V), and inclined at angle (θ) to the horizontal, then the work performed (E after a time interval (t) is calculated from the following equations:

$$E = WVt \sin \theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

Treadmill has been used extensively in human physiological studies as well as for studies involving animals. It still continues to be used for work measurement and for exercise. For example, if arm work is required in daily life, a treadmill test will indicate the power of the cardio-respiratory system, but does not demonstrate how far this can be realised during activities involving the m muscles (Rowell, 1977).

2.6.4 other Measurement Methods

Other methods also exist for the measurement of muscular work: One of such methods, most applicable to some laboratory studies of athletes, involve the use of various forms of free and tethered swimming (Magel, 1971; AcArdle et.al., 1971; Holmer, 1972; Rennie et.al., 1973).

For the case of field studies, another form of ergometry exercise called the step test is also used. The step test, proposed by Shephard (1967), was a modification of the widely known Clinical Master's Step. When designed for use in submaximum effort, this test consist of two 23 cm risers, climbed at rates of 10 to 25 ascents per minute (as paced by a metronome). When designed for maximal testing, it has a single 48 cm riser. The purpose of this arrangement was to allow an optimum pace of stepping in both the submaximal and maximal efforts; in particular the subject not standing poised to await the beat of the metronome at very slow rates of climbing (Wyndham and Sluis-Cremer, 1968; Shephard and Olbrecht, 1970), and yet avoiding the danger of tripping in maximum effort (Kasch et.al., 1965). Though more complicated designs of step have been proposed, these seem less suitable for field use (Shephard, 1980).

Another method, involving the use of electrodes to circumvent limitations imposed by other methods was developed by Kittredge et. . (1968). This method allows for direct instantanecus recording and measurement of the work output of any muscle or muscle group by positioning

the electrodes on them. The workrate is obtained from a electromyogram produced during the dynamic work.

Generally, most methods of work measurement have limitations, either in the form of time delay, error or non-consideration of varying body efficiency and/or inability to isolate the work measurement desired.

2.6.5 Work Measurement Methods and Physiological Indices

Though the work measurement devices described in s .ion 2.6 represent specialized equipments that are used directly in the evaluation of work done in a particular pattern, normally under laboratory conditions, they become unhelpful in situations where work is performed in the open, using tools or machines, as in agriculture.

Fortunately, linear relationship exist between physiological indices and rate at which work is performed. This means that any type of work could be measured indirectly by employing the following two steps:

(i) using a work measurement device to calibrate workrate against any convenient physiological index for a particular subject;

(ii) using the calibration graph to evaluate work done in the field after obtaining the relevant physiological index of the subject during or after the performance of the actual work.

Shephard (1980) has, however, indicated that results which are predicted are preferable to the alternative procedures, such as the following:- reporting the workrate at, say, a heartrate of 170 beats per minute (Wahlund, 1948); the heartrate at an oxygen consumption of, say, 1.5 L/min (Cotes, 1966) or the volume of maximum oxygen consumption as estimated from a linear regression equation which is based on measurements of heartrate at a fixed workload (Fox, 1973).

Prediction methods can be so arranged that all subjects are carried to a comparable submaximal stress (e.g. 75% or 85% of maximum oxygen intake) as judged from a target heartrate (Shephard, 1980). Table 2.8 shows the target heartrates corresponding to approximately 75 percent of aerobic power for different ranges of age groups.

TABLE 2.8: AGE GROUP AND TARGET HEARTRATES AT 75% AEROBIC POWER

Age (Years)	Heartrate (Beat/min)
20 - 29	160
30 - 39	150
40 - 49	140
50 - 59	130

Source: Shephard (1980).

The accuracy and the validity of test measurements for working capacity can be influenced by many details of technique, such as the calibration of the bicycle ergometer

(Cumming and Alexander, 1968), as well as the state of the test room and the condition of the subject.

Rowell et.al. (1964) had previously suggested 17°C as an optimum laboratory temperature, but the International Biological Programme (1974) recognized the conflict between the ideal and the possible under field test conditions. It recommended a room temperature of not more than 22°C, with the possibility of a further increase of 1°C to 2°C over this figure if a fan is provided. The initial emotional increase of heartrate should be minimized, both during submaximal effort (Antel and Comming, 1969) and maximal effort (Shephard et.al., 1974) through an appropriate schedule of habitation. Equally, it was important for the subject to avoid exposure to extremes of climate and physical activity on the day preceding examination, to ensure adequate sleep on the preceding night, and to avoid the use of alcohol, drugs and food immediately before the test (Jones and Haddon, 1973).

2.7.0 ENVIRONMENTAL EFFECTS ON WORK PERFORMANCE

Environmental factors known to influence the work performance of a subject can be classified into two groups. These are the thermal and non-thermal factors.

2.7.1 Thermal Factors

There are three ways in which a human can adjust to a hot or a cold environment. These are by adaptation, acclimation and acclimatization. According to Miller and

Horvath (1981), these mechanism can compensate rather effectively for exposure to heat, but not so effective in compensating for a cold environment.

Whilst adaptation implies a genetic change as a result of natural selection, acclimation refers to physiological changes in response to ambient temperature changes (e.g. sweating or shivering). Acclimatization refers to more enduring changes in physiological mechanisms that enable an individual to work in an extreme environment such as the tropics (Horvath, 1979).

(i) Heat and Working Capacity

If submaximal work is performed in a hot climate, the pulse rate tends to be higher than in a temperate region, even in the early stages of activity (Shephard, 1980), and the heat exposure reduces the endurance for sustained work (Saltin, 1964).

Astrand (1967) and Bonger (1968) have found that men who can work an eight-hour shift at 40 to 50 percent of aerobic power in a cool climate become fatigued when subjected to the same load under hot conditions, and that if maximum oxygen intake is measured at the end of the shift, it may be reduced by as much as 20 to 30 percent (Pirnary et.al., 1969). This deficit may be related to the fact that in hot environment, blood flow to the skin is increased, resulting in a hi er skin temperature. This causes heat losses by the physical processes of conduction, convection, evaporation and radiation from the subject's

body. The cooled blood then circulates through the body again, accepting more internal heat for transfer to the surface of the body. Consequently, heartrate increases in order to meet additional blood flow requirement (Miller and Horvath, 1981). The rectal temperature falls and sweat may begin (McCormick, 1976). The maximum sweat production that can be maintained by the average man throughout the day is 1.0 L/hr, corresponding to a heat loss of 600 kcal/hr (Miller and Horvath, 1981).

Wyndham (1966) compared the heat responses of "river" and "desert" bushmen and found that despite their similar genetic background, the desert dwellers had a higher sweat rate at a given rectal temperature and heartrate. He suggested this to be due to differences in the habitual activity of the two groups. The sweat rate reflected mainly the history of heat stress, whilst changes in rectal temperature and heartrate during effort were strongly influenced by the physical fitness of the individual.

According to Shephard (1980), there is some evidence that the linear regression relating rectal temperature (T_R,°C) and pulse rate (F_h) is flatter for tropical workers than for Europeans. Thus, Ladell (1955) established the following relationships for well-hydrated subjects.

for whites:

$$F_h = 33.2\ (T_R) - 1142.8 \quad \text{.....} \quad (12)$$

for Europeans:

$$F_h = 29.6\ (T_R) - 842.0 \quad \text{.....} \quad (13)$$

Few studies have been aimed at determining sex differences in reaction to hot environment. Some of the conclusions produced revealed that women have more problems than men in acclimatizing to heat (Burse, 1979), and from Kawahata (1960), females have a greater number of sweat glands, but the male sweat glands have greater activity and that, the onset of sweating in response to heat is also slower in females than in males.

With respect to physiological tolerance to uncompensable heat loss, Montain et.al. (1994) found out that full encapsulation of subjects in protective clothing reduces physiological tolerance. For full acclimatization to heat exposure, there is the need for the body to experience exercise in a hot environment. The hours of working should be modified to avoid the heat of the working day. Shade and a free access of air movement must be sought and the necessary task performed with an economy of movement. In any event, changes of behaviour, improvements of physical efficiency and habituation to subjective discomfort account for only a part of the gains in performance acclimatization. The physiological strains induced by a given combination of heat and exercise stresses are also lessened.

(ii) Cold and Working Capacity

H: loss from the body depends largely on the physical factors of environment. The rate of heat los from exposed skin is directly proportional to the temperature

difference between the skin and its environment (Burton and Endholm, 1955).

Changes from optimum environment to a cold one results in the skin becoming cold, rectal temperature rising slightly while the blood is routed away from the skin toward the central part of the body where it is warmed before flowing back to the skin area.

In his comparative ergonomic studies of male and female operators on selected farm tasks, Ali (1986) concluded that environmental changes affected both the output and energy expenditure for all tasks, with the highest output under cold weather. As regards energy utilisation, least energy was expended under cold weather for all tasks (Ali, 1986). Similar findings were reported by Nwuba (1981) in a study of human energy expenditure for selected agricultural tasks. With respect to this observation, Anderson (1967) explained that, acute exposure to cold can induce small improvements in working capacity through an increase in tone of venus reservoirs and a redirection of cardiac output from skin to active muscles. However, there is little evidence that cold in itself has any long-term effect upon physical fitness.

A study by Horvath and Freedman (1947) found that grip strength decreased by one-fourth, even though cold exposure was relatively of short duration.

(iii) Humidity Effect

Most climatic physiologists have distinguished hot climates into two main types. These are the hot-wet (high humidity) and hot-dry (low humidity) climates.

Generally, day time temperature in low humidity areas can exceed skin temperature and heat has to be gained by convection. This convective gain can be augmented by physical activity which increases air movement over the body surface.

For high humidity, evaporation of sweat from the surface of the skin will be relatively low. This leads to rapid increase in body temperature (Mathews et.al., 1971) with a resultant reduction in output. If the humidity is very high, with air having about 97 percent saturated moisture, almost no heat loss can occur by sweating and the working subject must attempt to dissipate heat by the slow process of convection during rest pauses (Shephard, 1980). Thus, high relative humidity tends to increase the energy expenditure requirement of a task (Suggs and Splinter, 1958). The consequent excessive environmental temperature, moist and stagnant air associated with high humidity has been shown by Vernon (1919) as well as Orenstein and Ireland (1921) to cause decline in output and also poses potential health hazards.

An environment unfavourable to heat dissipation (very low humidity) increases the stress on the circulation system. An accelerated heartrate and an elevated body temperature will be observed and a feeling of heat oppression and discomfort will be the subjective

consequence. If the water lost in the formation of sweat is not replaced, the working capacity will be further reduced (Adolph, 1947).

2.7.2 Non-Thermal Factors

Non-thermal factors, such as vibration, noise and dust are known to affect both mental and physical capabilities of man. Knapp (1966) observed that mental strains of getting a task done, preoccupied with weather and market trends together with physical factors such as heat, dust, vibration and noise reduce the mental capabilities of subjects.

Vibration is not only related to mechanical factors. It has significant effect on the extent of fatigue and similarly affects the sensitivities and reaction rates of the human operator in a man-machine system. Abrams and Suggs, (1966) studied the characteristics of chainsaw vibration with the aim of reducing the severity of the vibration impacted on the hands and arms, which has been found to be a potential cause of disabling effect. Other studies (Rossenger at.al., 1960; Manby, 1963) have shown negative effects of vibration on output as well as the comfort and health of operatives. Huang et.al. (1967) also cited vibration as one of the most important factors in the total environmental effect on man-machine system, from their studies on t' vibrational effects of different field operations on tractor operators in the vertical, transverse and longitudinal directions. In their study, Yamazaki

of kinesiology, which is the study of human movement in all its ramification (Barham, 1978; Cooper et.al., 1982).

Generally, anthropometry and the closely related field of biomechanics deal with the measurement of the physical features and functions of the body, including linear dimensions, weight, volume, range of movements and the like (McCormick, 1976). Anthropometric criteria fall into four main categories (Pheasant, 1991) dealing with questions of clearance, reach, posture and strength.

2.8.1 General Approach to Problems

For any practical design purpose, anthropometry requires that the "user population" be defined. These include all those who will likely use the design product during its useful life. Description can be either explicit or ill-described, so as to allow only gross approximations to their anthropometry measurements (Roebuck et.al., 1975).

The relevant data, with respect to design conceived, are then obtained. These could be simple segment dimensions, strength, limit of joints movement, reach, visibility, etc. Many methods exist for analyzing these data for the evolution of practical design criteria, but Helander (1981) has emphasized that the standard practice in anthropometry is to design spaces to accommodate 90 percent of the population, disregarding the upper and lower 5 percents. For this reason, anthropometric data are often expressed in terms of the 5th, 50th and 95th percentiles, as given in Table 2.9.

Since body measurements have normal distributions, any percentile measure can be derived from the values of the mean (M) and standard deviation (SD) (Helander, 1981).

Table 2.9: **ANTHROPOMETRIC MEASURES**

Percentile	Description
50th	Average value of a body dimension (M). 50% of the population is smaller.
95th	95% of the population is smaller. It can be calculated from the formula: M + 1.65 (SD)..... (14)
5th	5% of the population is smaller. It can be calculation from the formula: M - 1.65 (SD)..... (15)

Source: Helander (1981).

It is important to realize that no person is average (50th percentile) in all body dimensions. A person of average height might be 5th percentile in sitting-height and hip-breath, and 95th percentile in arm-reach length (Helander, 1981). This emphasizes the need to design for a range of sizes only.

According to Roebuck et.al. (1975), defining a "user population" should be the first step towards the evolution of a design criteria. From the population, a representative sample is selected since it is economically undesirable to measure every individual in a population. Relevant data are evaluated, and statistical methods are employed to develop design criteria, specifying the range of each parameter for a product to be designed. In general terms, the measurements of body dimensions, according to McCormick (1976), falls into two classes, namely; structural and functional dimensions.

(i) Structural Body Dimensions

These dimensions are taken with the body of the subjects in fixed, standardized positions. Many different body features can be measured and these could have specific applications. However, measurements of certain body features have rather general utility.

(ii) Functional Body Dimensions

These are taken from body positions that result from motion, and are probably, more widely useful for most design problems. The emphasis on the use of these dimensions relates to the fact that in performing physical functions, the individual body members normally do not operate independently, but rather in concert. For example, the practical limit of arm reach is not the sole consequence of arm length; it is also affected in part by shoulder movement, partial trunk rotation, possible bending of the back, and the function that has to be performed by the hand. These and other variables make it difficult, or at least, very risky to try to resolve all space and dimension problems on the basis of structural body dimensions (McCormick, 1976).

2.8.2 General Principles for Task Designing

There are several general principles for designing a task, so that work posture does not inflict pain. Corlett (1979) has presented a list of important principles, as well as rules for body motions. Essentially, these

principles stress on the correct use of body momentum and gravity, the placement of tools, and the need for rhythmic and symmetrical motions to minimize fatigue and maximize productivity.

Rules for work posture include the following:

(a) The subject should be able to maintain an upright and forward facing posture during work;

(b) The back should be supported during sitting work. The weight of the body should be supported equally on both feet during standing work. Ideally, the task should permit the subject to adopt any of several equally safe and healthy postures without reducing productivity;

(c) The task should be visible with the trunk weight and the head either upright or inclined slightly forward;

(d) Work should be performed at a height below shoulder level. Even occasional exertion of force above the shoulder level should be avoided. Where light hand work must be performed above the shoulder level, upper arm rests must be available;

(e) Work should be performed with the joints at about the midpoints of their range of movement. This

is particularly important for the joints of the neck, trunk and arm;

(f) Muscular force should be exerted, so that large (groups of) muscles can be used. The direction of motion should be parallel with the limbs involved;

(g) When the repeated use of muscular force is required, the task should be designed such that the subject can use either arm or leg.

2.8.3 Principles in the Application of Anthropometric Data

In the application of anthropometric data, there are certain principles that may be relevant, each one being appropriate to certain types of design problems (McCormick, 1976).

(i) Design for Extreme Individual

In the design of certain aspects of physical facilities, there is a "limiting" factor which calls for a design that would specifically accommodate all individuals.

A minimum dimension of a facility would be based on an upper percent value of the relevant anthropometric feature of the sample used, such as the 95th percentile. If the physical facility in question accommodates large individuals, it would also accommodate all those who are smaller in size.

On the other hand, maximum dimensions of some facilities would be predicted on lower percentiles, such as the 5th percentile, of the relevant anthropometric feature. Distance of control devices from an operator is an example. If those with short functional arm-reach can reach a control, then persons with longer arm-reach, generally, could also do so. Thus it is frequently acceptable to use the 95th and 5th percentile values for maximum and minimum dimensions in practical design (Helander, 1981; Pheasant, 1991).

(ii) Design for Adjustable Range

There are certain features of equipment or facilities which would be designed, preferably adjustable, in order to accommodate people of varying sizes. Examples are: the forward-backward adjustments of chairs. In the design of adjustable items, it is fairly common practice to do so for the range of cases from the 5th percentile to the 95th percentile (McCormick, 1976).

(iii) Design for the Average

In the domain of human anthropometry, there are few people (if any) who would really qualify as average. Since the concept of the average person was a myth, there was some rationale for the common proposition that physical equipment should not be designed for the average individual.

Recognizing this, however, McCormick (1976) has proposed for the consideration of average values in the design of certain types of equipment or facilities, specifically, those for which (for legitimate reasons) it is not appropriate to pitch the design at an extreme value (minimum or maximum) or feasible to provide for an adjustable range. As an example, the check-out counter of supermarkets are built for the average person, but yet it accommodates all individuals.

2.8.4 Some Applications of Anthropometry

A workplace envelope must be compatible with the anthropometric dimensions of the particular population who will be using the proposed equipment. It is also important to lay out the work space according to the ways it will be used. This requires consideration of physiological factors such as procedural logic, naturalness of relationship and standardization to minimize learning time (Woodson, 1964).

A problem of cock-pit dimensions in a single-seat fighter plane was solved by the method of "experimental trials". This included collection of data, erection of mock-up and test for suitability (Morant, 1954).

Functional use of tools should be compatible with motion inventory and strain capacity of the human body (Roebhck et.al., 1975). In this respect, Nwuba (1981) conducted human energy studies on selected agricultural hand tools. He discovered that for all tools considered, tool types had significant effect on response variables

(i.e heartrate, energy expenditure/output and physical output). Most tools examined were short-handled. Modified types, based on anthropometric considerations were found to be better in performance and energy demand.

Wagami (1983) also conducted a survey in which he collected anthropometric data of farmers. He discovered, after data analysis, that the tools being used by the farmers were deficient in design. Consequently, a tool design criteria was evolved and useful recommendations to enhance productivity was made.

Anthropometric data are of particular importance when comparing the working capacity of populations that differ in size. In addition to the traditional indices of height, weight and skinfolds thickness, it is useful to add dimensions that will characterize the relative lengths of the trunk and limbs, the shape of the chest, the body type (masculinity) and the body build (ectomorphic, mesomorphic or endomorphic) (Shephard, 1980).

Regarding Shephard's (1980) assertion, Ali (1986), in his ergonomic studies, realized that even though the sizes of segments for gender groups varied, proportions of segments in relation to stature was more or less the same. Using anthropometric principles, he then developed hand tools sizes for female subjects which were significantly different from those calculated for males.

CHAPTER THREE

3.0 INSTRUMENTS AND METHODS OF STUDY

This chapter describes the instruments used in this study. In addition, basis for selection of subjects and their physical characteristics are outlined. Lastly, detailed, step by step, procedure adopted in this project is given.

3.1.0 Instruments

The following instruments, with varying sensitivities, were used to conduct the appropriate measurements involved in these studies:

(i) Weighing Balance;

(ii) Weighing Scale (50 kg capacity);

(iii) Electronic Weighing Scale (Mettler PN 1210)

(iv) Height Scale

(v) Stethoscope

(vi) Stop Watch

(vii) Laboratory Clock

(viii) Hygrometer

(ix) Can sieves

(x) Oven (100°C capacity)

(xi) Tachometer

2.0 Basis for Selection of Subjects

Female subjects were used in the studies. This was because most studies have shown that oil extraction is more

or less, an exclusive women's activity. The subjects selected have age range of 30-49 years. This range was cited as the most representative of women dominating the traditional groundnut processing industry in Nigeria (Dunmade, 1991). Previous knowledge (i.e. level of experience) in the kneading operation was also considered as a major factor in the selection of subjects. All subjects had reasonable experience in the oil processing activity. This factor enabled them to perform the various operations knowledgeably and with minimum interference and/or uncertainty while performing required task.

In all, three female subjects were selected. These are referred to as A, B, and C throughout this presentation. Their physical characteristics, including weight, height and basal metabolic rates, calculated from equation (2), are given in table 3.1.

Table 3.1: Physical Characteristics of Selected Female Subjects

SUBJECT	LEVEL OF EXPERIENCE (Years)	AGE (Years)	WEIGHT (kg)	HEIGHT (cm)	BASAL METABOLIC RATE kcal/day	kcal/min
A	4	35	58	158	743.20	0.516
B	6	36	46	159	625.10	0.434
C	7	40	50	158	638.20	0.447

3.3. METHODOLOGY

A three-way study approach was used in conducting this research work. These approaches include Preliminary Investigation; Development of Interventions; Evaluation of Interventions.

CHAPTER FOUR

4.0 PRELIMINARY INVESTIGATION

To understand existing methods adopted by traditional processors and identify areas of intervention, detail study was carried out on existing methods. This is referred to as the preliminary investigation.

This preliminary investigation involved detail work study of the existing methods and tools as used in traditional groundnut processing. Also included among tools in this study are existing conventional grinding mill and the IAR Modified Pestle. This is because the two tools have been adopted by some traditional groundnut-oil processors.

4.1 Methodology

To carry out this study, subjects were observed performing each of the processing tasks as they normally do. At the end of each specific task, performance parameters which include operational time and ergonomic observations (including subjective judgements) are noted.

4.2.0 Observations And Inferences

Observations made as well as complaints by the subjects are summarized in table 4.1 below. Analysis of these result established that the most problematic task, in terms of drudgery, was the kneading operation. The deskinning op ation was also problematic with respect to operational posture. Rolling and cutting of groundnut cake with the hands appeared to be the most time consuming

Table 4.1: METHOD STUDY OF TRADITIONAL OIL PROCESSING TECHNIQUES

PROCESSING TASK	OBSERVATIONS ON OPERATOR - TOOL INTERACTION	OPERATOR'S COMPLAINT ON TOOL/METHOD
a. Roasting	Interaction is fairly compatible. Neither operational constraint nor restrain was observed	None
b. Deskinning of Roasted Groundnut	IAR Deskinner (Table 2.5.ii) was used: i. Problem was observed relating to proper hold of the rubbing plate by operator's fingers ii. Posture problem - the task is performed close to the ground in a kneeling position, with the crater on the floor.	i. Muscular pains in the shoulders, close to the neck during operation. ii. The kneeling and squatting postures were not convenient. iii. No complaint against tool performance.
c. Winnowing	Interaction is fairly compatible based on the observation that the quantity of groundnut winnowed at each turn measured approximately 0.5kg	None
d. Grinding	Improved tool (Table 9.vi) was used. Excessive noise is provided by the machine resulting in discomfort of operator	Excessive noise from the milling machine
e. Primary Extraction Using Traditional Tool (Table 8.viii c)	i. Not compatible with respect to posture ii. Level of drudgery involved is very high. iii. Continuous random displacement of the mortar on the ground as kneading operation progresses. This was observed to be due to the hardening of groundnut paste in which the pestle tends to get stuck.	i. Random displacement of mortar makes operation inconvenient. ii. Difficulty in turning the pestle as the operation progresses. iii. Muscular pains in the arms, legs, shoulders and the back. iv. Operation very tiresome v. Tool usage inconvenient.

f.	Primary Extraction Using IAR Modified Pestle (Table 9.vii.a)	i. Fairly compatible with respect to posture. ii. Close grip of the pestle with both hands in standing position tend to ontract operator's upper body around the chest and breast. iii. Radius of motion vary and is dictated by operator's outstretched arms. This variation results in operator's upper body also undergoing circular motion, making the operational stance of the operator unstable. iv. Restriction is imposed on movement of pestle, with respect to operational control resulting in continuous random displacement of mortar as operation progresses.	i. Restriction isimposed on movement of pestle by the pivot mechanism, resulting in continuous random displacement of mortar as operation progresses. ii Muscular pains in the arms and shoulders. iii. Task difficult to control due to the random displacement of the mortar during the of motar during the operations. iv. Operation very tiresome and requires lot of energy (effort) to accomplish. v. Tool less suitable compared to the traditional pestle by the pivot mechanism, and manourvrebility.
g.	Rolling of Cake, or secondary Extraction (Table 8.viii)	Interaction is fairly compatible. No constraint or restrain imposed on operator.	Operation is time consuming.
h.	Frying	Interaction in compatible. Neither operational constrain nor restrain was observed.	None

operation. It was realized that by introducing appropriate interventions for these three problematic operations, the ease, output and profitability of the system could be enhanced.

4.2.1 Explanations for Problematic Tasks

(i) Kneading Operation

(a) Using Traditional Pestle

The traditional pestle (Plate 1) has an approximate length of 200 cm and diameter of about 6 cm. During the kneading operation, the pestle was observed to have an unlimited degree of manouvreability, as illustrated in figure 4.1. At the start of kneading, motion of the pestle was about the y - y axis, with an additional pounding motion along the y - y axis. As the paste hardens, pestle motion about the y - y axis becomes difficult to achieve. Consequently, the



Plate 1: Traditional Pestle and Mortar (placed in floor cavity support)

MECHANICS OF MOTION

1. Rotational motion of pestle about Y-Y axis at start of operation along a path of circumference πX.
2. Motion in (1) changes as paste hardens. Rotation about Z-Z axis with wall of mortar serving as fulcrum to pestle.
3. Additional motion along the Y-Y axis to provide pounding action on paste.

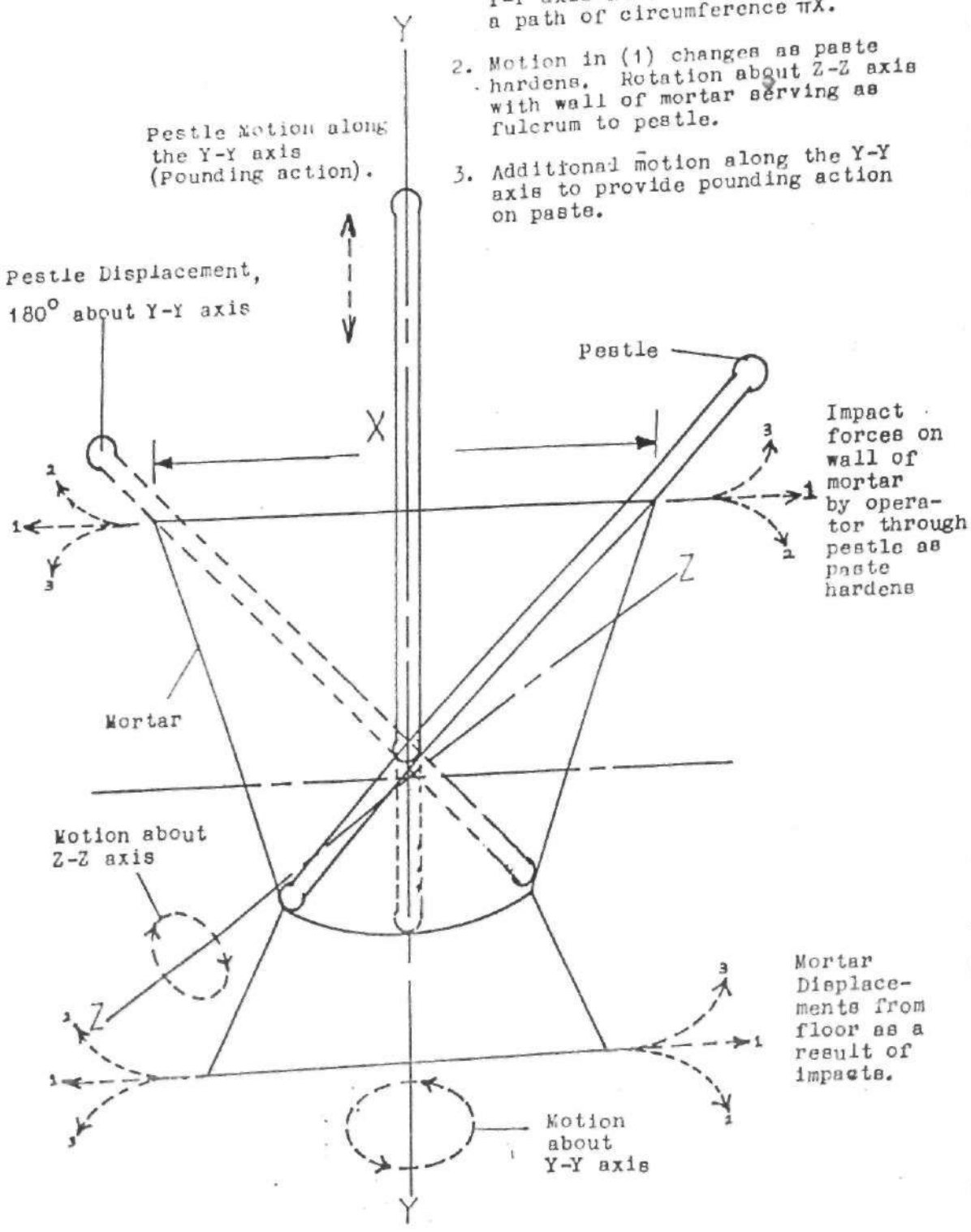


Figure 4.1: Mechanics of Kneading Using Traditional Pestle and Mortar.

pestle motion is oriented about the z - z axis along which it is easier to operate. At the oil-forming stage, the freedom associated with the pestle motion appeared to help in pressing (splitting up) the hardened and clotted groundnut cake against the inner walls of the mortar. This action was observed to encourage the release of oil entrapped in the clotted cake.

(b) Using IAR Modified Pestle

Though the IAR modified pestle (Plate 2) has the same dimension as the traditional pestle, it provided an element of ease during the operation when compared to the traditional pestle. This was observed at the stage where the groundnut paste hardened. Yet, the restriction on the pestle motion at the pivot appeared to make the IAR pestle less compatible. Also, the design similarity factor between the IAR pestle and the traditional pestle appeared to introduce some element of operational complications. This was because the subjects found it difficult to operate with this pestle when the paste hardened. Consequently, they ended up adopting similar pestle motion techniques used with the traditional pestle, despite the fact that the IAR pestle has a defined motion path (i.e. about y - Y axis) and a restricted degree of freedom, as illustrated in figure 4.2. As a result, the operators ended up creating excessive impact between the rod (pestle) and the walls of the casing pivoting at. This resulted in a severe "rocking" motion of the mortar. The instability of the mortar



Plate 2: IAR Modified Pestle and Mortar (placed in cavity support)



Plate 2: IAR Modified Pestle and Mortar (placed in cavity support)

MECHANICS OF MOTION

Rotational motion about the Y-Y axis by pestle throughout operation along a path of circumference πD. (which is less than πX in fig.4.1).

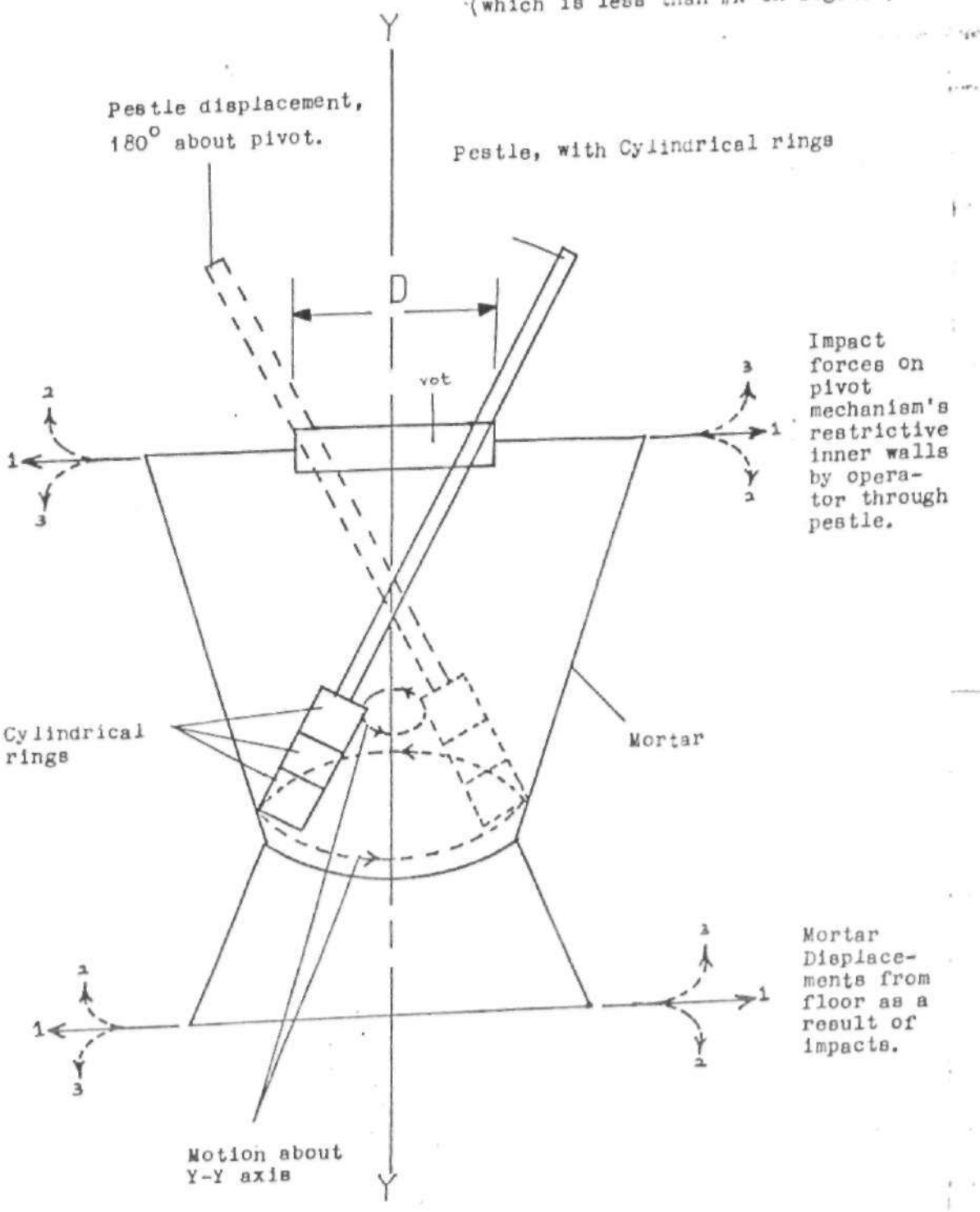


Figure 4.2: Mechanics of Kneading Using IAR Modified Pestle and Mortar.

resulted in the subject attempting to knead and at the same time holding down the mortar. AT the oil-forming stage, attempts to apply similar technique as with the Traditional Pestle also resulted in the operators adding to the instability of the mortar. This effect was found to be related to the fact that the restriction on the pestle motion (at its pivot) made the idea of pressing the clotted cake against the inner walls of the mortar unpractical.

(ii) Deskinning Operation

The existing apparatus adopted for deskinning the roasted groundnut was designed specifically for sieving threshed sorghum. Its use was observed to present the operators with problem of posture. This was because the operation has to be performed in a kneeling posture with the apparatus on the ground. This action is shown in Plate (10). It was also observed that after the rubbing operation, the entire apparatus had to be lifted off the ground. This was done in order to transfer both the deskinned nuts and the removed skins into a winnowing basket for final separation. The winnowing operation also requires a standing posture with a repetitive lifting and lowering of the two arms holding the basket. This was also noted to create an additional postural problem and operational discomfort during deskinning task.

(iii) **Cake Rolling and Cutting Operation**

Due to the soft nature of the cake, it was realized that the rolling process requires carefulness. This was because, the operator has to be applying small pressures and continuous oscillatory motion with the hand, as illustrated by Figure 4.3. This simultaneous action was observed to be necessary in order to produce a good roll. It was also to ensure that the required diameter of each roll meets the operator's expectation. The correct size was determined intuitively.

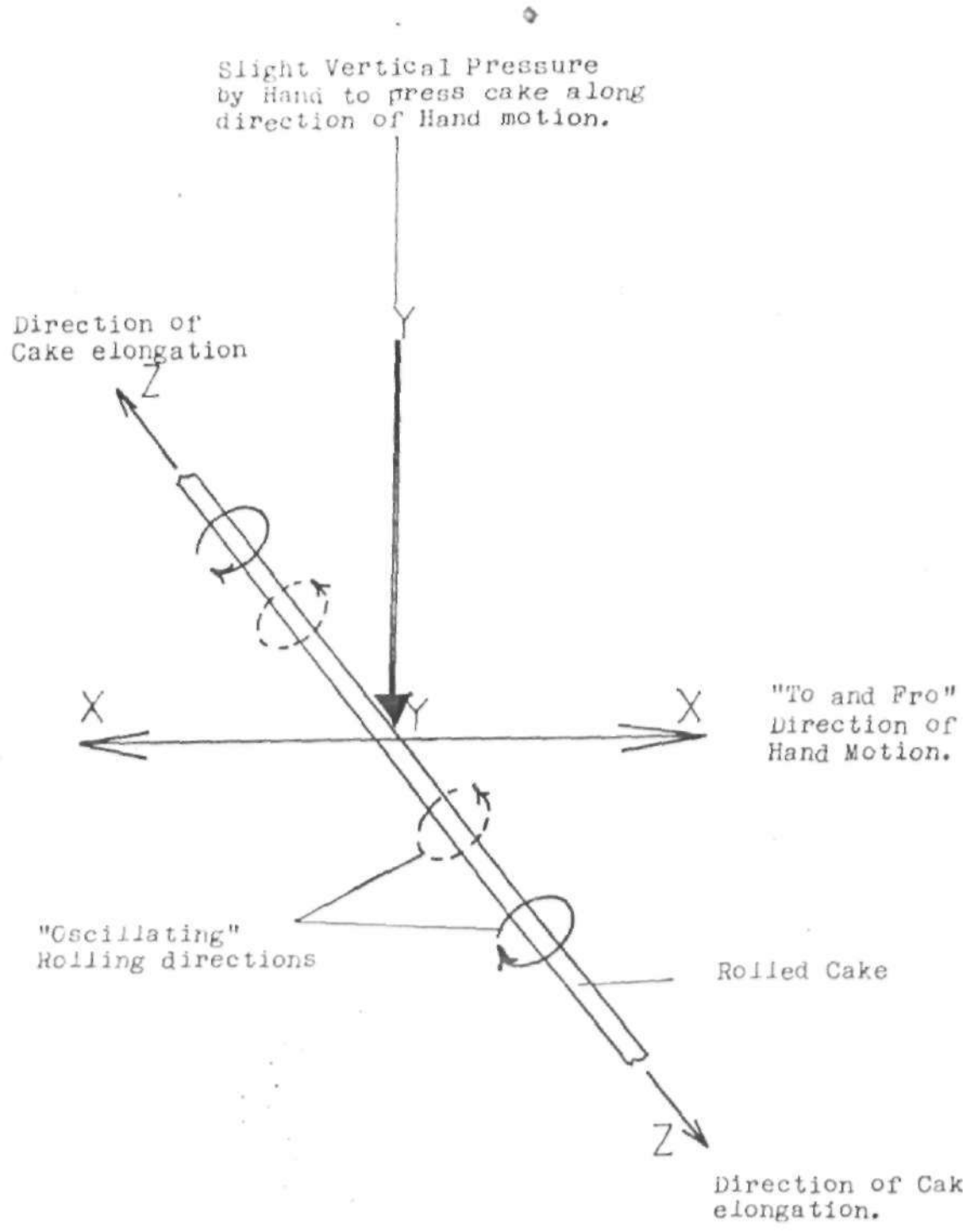


Figure 4.3: Mechanics of Hand Rolling and shaping of groundnut Cake.

CHAPTER FIVE

5.0 DEVELOPMENT AND EVALUATION OF INTERVENTIONS

Data and observations from primary study were critically analysed. Areas of intervention were identified based on observed constraints. Ergonomic principles were then used to design suitable tools. Suitable materials were then selected to develop the designs. Development of the designs was also facilitated by the construction of mock-ups through paper modelling.

5.1 Design Approach For Interventions

The use of both established and evolved engineering principles as well as product formulation and mock-up (using paper models) resulted in the development of interventions for the three selected problematic tasks namely; kneading, deskinning and cake rolling.

5.1.1 Kneading Operation

Considering the importance of the kneading operation in the groundnut-oil extraction system, analysis of the problems associated with the existing tools, and a further study of the operational principle of the 10-litre Bench Mixer resulted in identifying a possible intervention. The intervention was perceived to encompass most of the features of both the traditional pestle and the IAR Modified Version, and also the operational principle of the Bench Mixer. This was to allow for the elimination or reduction of the excessive drudgery and constraints identified with the existing pestles.

The operational method of the Rotary Groundnut Kneader (intervention) was designed to differ from those of the traditional and IAR pestles. This approach was adopted in line with an ILO (1979) recommendation to the effect that, a new method should really be different from the old. This was from the realization that operatives tended to slip back into an old way, especially if they are not young and have spent many years doing the job, as was the case with traditional groundnut-oil extraction. This approach was in order, judging from the operational similarities between the traditional pestle and the IAR Modified pestle (supposed to be an improvement of the traditional pestle) and the consequent problems encountered by operators (as explained in section 4.2.1).

(i) **Design and Materials of Rotary Groundnut Kneader**

The object of the design was to introduce into the kneading task an element of economy in the application of human physical effort.

The Rotary Kneader (shown in Plate 3) consists of the following components - a wooden shaft; a wooden torque plate; a wooden crank handle; a ball and roller bearing (6305); two wooden cylindrical rings (same height, but different diameters); eight wooden knife-edged fingers; four L-shaped metal brackets; a wooden casing; a bolt and nut (6 inches).

(Detail drawing of the mechanism given inside pocket of back cover).

The bearing holds the shaft and is itself housed inside the casing. The casing is in two halves which are held in place by the U-shaped part of the bracket. The L-shaped part of the bracket facilitate the mounting of the mechanism. The fingers are fixed at acute angles on the surface areas of the rings. Each ring contains four fingers. The fingers arrangement are such that two are fixed parallel to each other facing upwards, and the other two also fixed parallel to each other facing downwards. These positioning are made such that the diammetrical link between those facing upwards and those facing downwards is perpendicular. The two finger-studded rings are fitted to the lower end of the shaft and held in place by wooden screws. The ring with the larger diameter was positioned above that with the smaller diameter. The tonque plate was fitted centrally to the top cross-sectional area of the shaft. The torque handle was also fitted on the tonque plate, using a bolt and nut (with some degree of rotational freedom).



Plate: 3: Rotary Groundnut Kneader on Mortar (on Floor)

Table 5.1 below gives the summary of estimated anthropometric measures for stature (overall Height), forearm length, nd standing-elbow height from a sample data for fifty women (appendix A4.7 - A4.9)

Table 5.1: **Esatimates of Selected Anthropometric Measures For Women**

Body Segment	Anthropometric measure (cm)		
	5th Percentile	50th Percentile	95th Percentile
Ovwerall Height (Stature)	148.70	160.8	171.66
Forearm Length	24.02	27.04	30.06
Standing-Elbow Height	91.28	99.30	107.32

In order to ensure that the mounted mechanism accommodates smaller operators, the operational height of the mounted mechanism was chosen as the sitting-elbow height for the 5th percentile female.

The criteria for the design of the torque handle was diameter. The same holds for the torque-plate design. The thickness of the torque-plate was selected from the range 5-10 cm, based on the mechanical properties and grain direction of the selected wood. The weaker the strength of the wood, the larger the thickness.

(a) **Torque Handle Design**

Criteria is diameter (D), and Length L) but,

$$D = \frac{C}{\pi}$$

where C = circumference = Hand Length

According to Ali (1986), Segment ratio for hand = 0.11 H = C therefore, torque handle diameter is

$$D = \frac{0.11}{\pi} H$$

where H - stature (i.e. overall height).

5th percentile female stature was used in order to accommodate smaller operators.

Also the contact Length of the torque handle (to accommodate two hands) was developed using the criteria (Ali, 1986) for grinding stone (Ali, 1986), i.e.

$$L = \frac{4}{3} \times \text{Hand Length}$$

$$= \frac{4}{3} \times (0.11 \ H)$$

therefore,

$$L = 0.147 \ H$$

95th percentile female stature was used in order to accommodate bigger operators, and also allow for simultaneous grasp with both hands.

From table 5.1, stature for 5th percentile is,

$$H = 148.70 \text{ cm}$$

Hence, calculated Torque - Handle Diameter is

$$D = \frac{0.11}{\pi} \times 148.70 \text{ cm}$$

$$= 5.21 \text{ cm}$$

Stature for the 95th percentile is,

$$H = 171.77 \text{ cm}$$

Hence, calculated contact Length of the torque handle is,

$$L = 0.147 \times 171.66 \text{ cm}$$

$$= 25.23 \text{ cm}$$

(b) **Torque - Plate Design**

Criteria is diameter of torque plate (TPD). It was derived from the following analysis:

According to Pheasant (1991), the fastest and most accurate hand movement is achieved when it is made outward rather than inward, and obliquely across the body at an angle of 45° to 60°. Thus by adopting a general angle, within the given range, the interaction between operator and plate during cranking could be illustrated by the diagram in Figure 5.1 below: where:

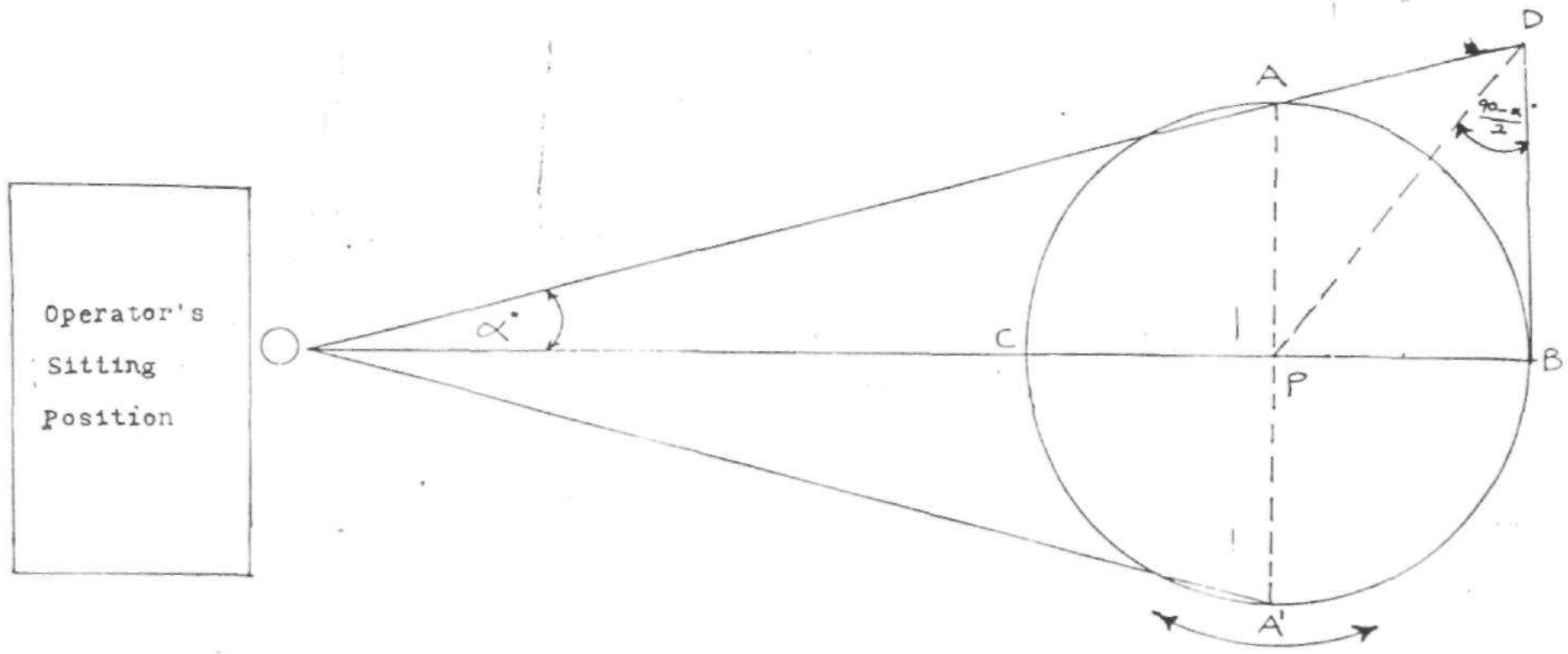


Figure 5.1 : Illustration of Operator's Hand Positions During Cranking Action.

A' = Poition of operator's hand during outward motion (cranking anti-clockwise with right hand) or inward motion (cranking clockwise with right hand) at maximum oblique displacement to the body.

A = Poition of operator's hand during outward motion (cranking clockwise with left hand) or inward motion (cranking anti-clockwise with left hand) at maximum oblique displacement to the body.

B = Position of operator's hand at the maximum turning point of both the inwarrd and outward motions.

C = Position of operator's hand at the manimum turning point of both the inwarrd and outward motions.

P = Point of rotational motion.

0 = operator's sitting position.

$|AP| = |BP| = |cP| = |PA'|$ = torque-plate radius

$\overline{OA}$ = normal arm position at effective displacement angle, α^{o}, to the body

$\overline{OB}$ = maximum stretch of the arm during cranking action (i.e. forearm length)

$\overline{OC}$ = minimum stretch of the arm (Hand Length) during cranking action.

Applying simple trignometry:

$$\frac{|DB|}{|OB|} = \tan \alpha$$

Therefore,

$$|DB| = |0B| \cdot \tan \alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Also,

$$\frac{|BP|}{|DB|} = \tan \left(\frac{90 - \alpha}{2} \right)$$

therefore,

$$|BP| = |DB| \cdot \tan\left(\frac{90 - \alpha}{2}\right) \quad \ldots\ldots\ldots\ldots \quad (20)$$

Substituting equation (19) in equation (2), the following relation was obtained.

$$|PB| = |OB| \cdot \tan\alpha \cdot \tan\left(\frac{90 - \alpha}{2}\right) \quad \ldots\ldots\ldots \quad (21)$$

Introducing the angular displacement limits given by Pheasant (1991), the following analysis were made, using equation (21):

(1) for $\alpha = 45°$,

$$|BP| = |OB| \times (\tan 45) \times \tan\left(\frac{90 - 45}{2}\right)$$

$$= |OB| \times \tan 45 \times \tan 22.5$$

$$= |OB| \times 1 \times 0.414$$

$$= 0.414 \ |OB| \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 22$$

(2) for $\alpha = 60°$

$$|BP| = |OB| \times (\tan 60) \times \tan\left(\frac{90 - 60}{2}\right)$$

$$= |OB| \times \tan 60 \times \tan 15$$

$$= |OB| \times 1.732 \times 0.268$$

$$= 0.464 \ |OB|$$

therefore at $\alpha = 60°$,

$$|BP| = 0.464 \ |OB| \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 23$$

Taking the operators forearm Length ($|OB|$) to be equal to X cm, then for fastest and most accurate hand movement during cranking action, the torque plate radius ($|BP|$) was selected from the range 0.414 X - 0.464 X.

Consequently, the torque plate diameter (TPD) was obtained by multiplying the torque radius by a factor of 2.

An adjustment factor of 20 cm was added to the diameter to cater for construction off - cuts. Hence

$$TPD = 2/BP + 20 \text{ cm} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

Thus, the range of values for the TPD can be represented as follows:

TPD range = (0.828 - 0.928) X + 20 cm

For the constructed mechanism, the torque plate diameter was calculated from the following relation:

TPD = 0.929 X + 20 cm.

5th percentile female forearm Length is used to fit smaller users. From table 5.1, X = 24.02 cm.

Hence, calculated Torque - plate diameter is:

TPD = 0.928 X + 20 cm

= (0.928 x 24.02) + 20 cm

therefore TPD = 42.29 cm.

(ii) Operational Principle

The Rotary Kneader mechanism was designed to be operated in a sitting posture, without necessarily a back support, as shown in Plate (8).

Rotational motion of the shaft on the fixed roller ball bearing about the Y - Y axis was provided through a cranking action by the operator. The rotational action causes the groundnut paste in the mortar to be stirred along the direction of shaft motion. This was achieved

through the influence of the cylindrical rings and the knife-edged fingers, which serve as stirrers.

Additionally, the arrangement of the fingers caused the lifting (climbing) and throwing (falling) action of the paste along the Z - Z axis. These multi-directional motions are illustrated in Figure 5.2. The combined effect of these motions resulted in the simulation of complete centrifugal action on the oil molecules in the groundnut paste (i.e., churning effect). As the paste starts to get hardened and clotting in the cause of kneading, the knife-edged fingers cut through them with relative ease. This factor reduces the resistance to shaft motion during the paste - cake transition. As a result, an operator can continue with operation upto the end of task with a relatively lower effort.

MECHANICS OF MOTION

1. Rotational Motion generated by fingers and about shaft and cylindrical rings about the Y-Y axis simultaneously.
2. Additional rotational motion generated about each finger.
3. Apparent lifting and falling motion along the fingers.
4. No impact action between mortar and mechanism.

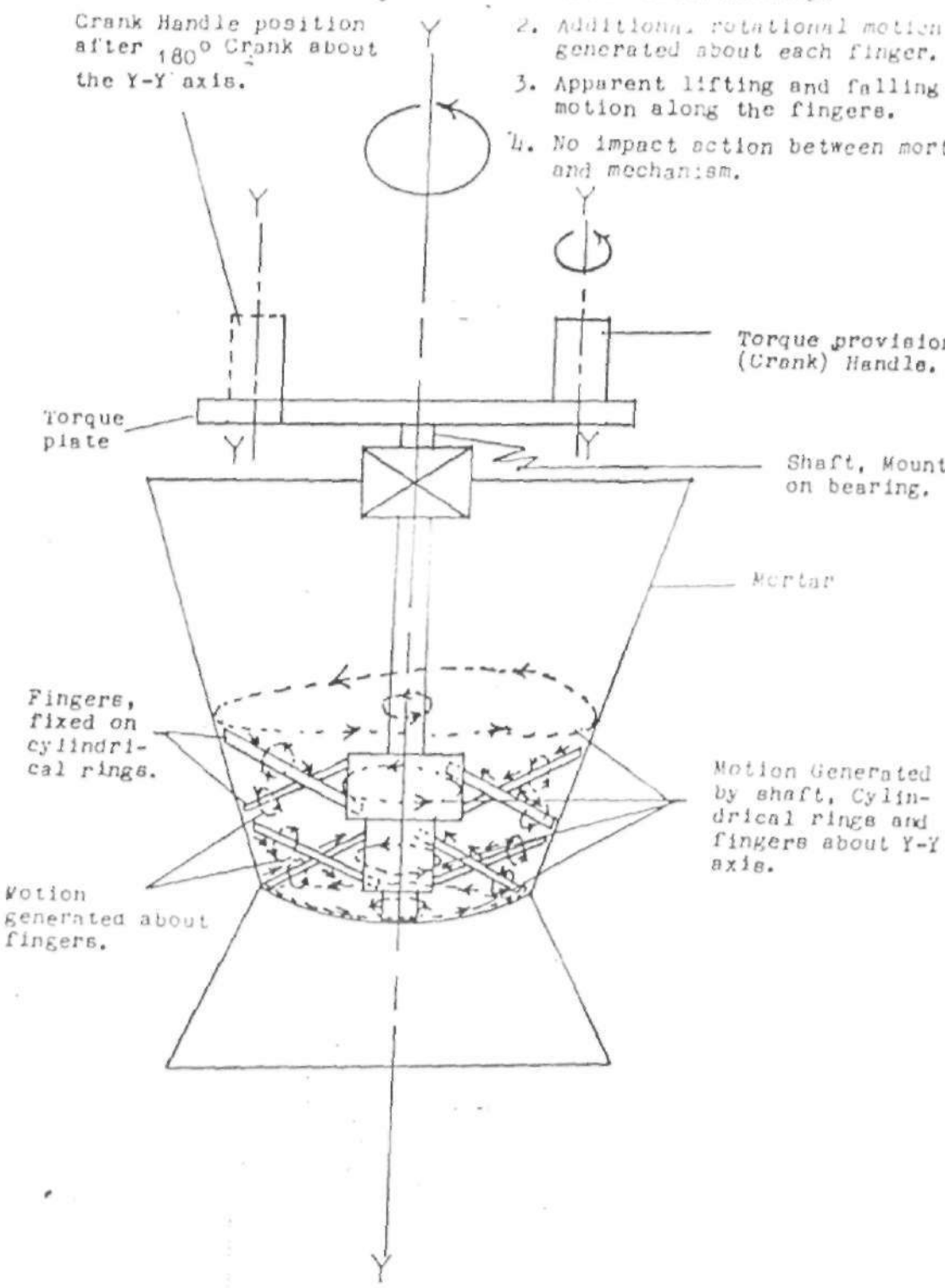


Figure 5.2 : Mechanics of Kneading Using Developed Mechanism and Mortar.

5.1.2 Deskinning Operation

The improved IAR Deskinner was designed to provide improved operational posture, ease of collection of deskinned groundnuts and integrating the winnowing task into the deskinning process. Thus by raising up the operational height of the existing apparatus and introducing a product discharge outlet, the operator could perform the task with relative ease. The height advantage could also encourage discharge of skins as the operation progresses, and possibly eliminate the winnowing task.

(i) Design and Material of Improved IAR Deskinner

The existing IAR Deskinner consisted of a wooden sieve and a rubbing plate (refer to Appendix 3). The wooden sieve was made up of a rectangular wooden crate provided with a sieve bottom, made of galvanized metal sheet (0.5 mm sieve diameter).

For the Improved Deskinner (Plate 4 the components are as follows: a rectangular wooden sieve (one side open); four wooden supports (Legs); a gate (discharge outlet). (Detail drawing of the apparatus given inside pocket of back cover).



Plate 4: Assembled Improved IAR Deskinner with Rubbing Plate

The Rectangular Wooden Sieve is made up of three enclosed wooden walls, provided with a metal sieve bottom. The sieve bottom extended beyond the open side of the wooden walls, where it is tilted down to serve as a discharge outlet. The wooden legs support the wooden sieve at the operational height. The gate at the outlet is made up of a rectangular metal sheet, held at two parallel (vertical) sides by rectangular shaped wooden supports.

In order to accommodate both smaller and bigger users, the design criteria for a fixed operational height was taken as the standing-elbow height (W) for the 50th percentile female. From table 4.2, fixed operational height, W = 99.30 cm.

Alternatively, all users could be accommodated by choosing a design criteria for adjustable operational height ranging from 5th to 95th percentiles female standing elbow height. From table 5.1, elbow height for the 5th percentile is 91.28 cm, elbow height for the 95th percentile is = 107.32 cm. Therefore, the range of operational height for the adjustable improved deskinner is,

$W_{adjustable}$ = 91.28 cm to 107.32 cm

(ii) **Improved Operational Principle**

The roasted groundnuts are placed in the deskinner and the discharge outlet closed. The groundnuts are then rubbed against the sieve bottom using the rubbing plate. The operator adopts a standing posture with the upper part

of the body slightly inclined at the waist. This facilitates the "to and fro" motion of the arms during the rubbing operation. As the groundnuts are being deskinned, the removed skins are discharged through the sieve. This principle is illustrated by the action indicated by Plate (11).

At the end of the deskinning task, the products (deskinned groundnuts) are swept with the hand through the discharge outlet after removing the gate. These are then allowed to run down into a collecting source placed underneath. Remaining skins mixed with the product are blown away by natural wind as the discharge progresses.

5.1.3 **Cake Rolling and Cutting Operation**

A Cake-Roller Press (Plate 5) was also designed to replace the use of the hand in rolling and cutting the groundnut-cake. It consists of the following components: a feed-box; a hand press; a U-shaped sliding-cutter; a movable "false" bottom; a



Plate 5: Assembled Cake Roller Press.

perforated "fixed" bottom; feed-box support. (Detail drawing given inside pocket of back-cover).

The development of the Cake Roller Press was aimed at introducing some element of time economy in the process. It was also to help improve the quality control of the products by reducing the degree of hand contact, as far as possible. Thus the mechanism was designed to encompass both rolling and cutting operations within a short period of time.

(i) **Design and Material of Groundnut Cake-Roller Press**

The feed-box has a fixed bottom made of fibre glass (with ϕ 10 perforations). Below this fixed bottom is a false bottom which is movable. Below the false bottom is the sliding-cutter. The false bottom is made of plywood board whilst the sliding-cutter is made of wood, with a string serving as the cutter. A wooden hand-press, made up of a rectangular block and a horizontal cylindrical handle was also designed to fit into the fed-box. The sides and bottom of the press, as well as the inner walls of the feed-box are lined with fibre glass boards. This was done to prevent the cake from sticking to the wood surfaces.

In order to ensure a compatible grasp of the hand-press' handle, the diameter and contact length were used as the design criteria.

From previous calculations (Section .1.1 (i.a)) Handle diameter was 5.23 cm. Also the contact length was 25.23 cm. This length was doubled to give the handle a

wider span. Thus, the handle length was 2 x 25.23 cm = 50.46 cm.

(ii) **Operational Principle**

The cake obtained after the kneading operation is placed in the feed-box of the mechanism. The false bottom is then positioned directly below the fixed bottom such that it covers all the perforations. This was to prevent the cake from being extruded whilst under compaction inside the feed-box. The compaction is done by pressing the cake, using the hand press. Some entrapped oil in the cake are then recovered and the cohesion among the cake molecules improved. Afterwards, the false-bottom is slided away to expose the holes on the fixed bottom. The compacted cake is then pressed slowly, applying the pressure gradually until the expected rolled size of cake are extruded below the fixed-bottom. At this stage, the cutting mechanism is slided across the extruded product to cut them off. These are then collected in a container positioned below the mechanism's bottom. The procedure is repeated until the cake finishes. The operational principle is illustrated by Fig. 5.3.

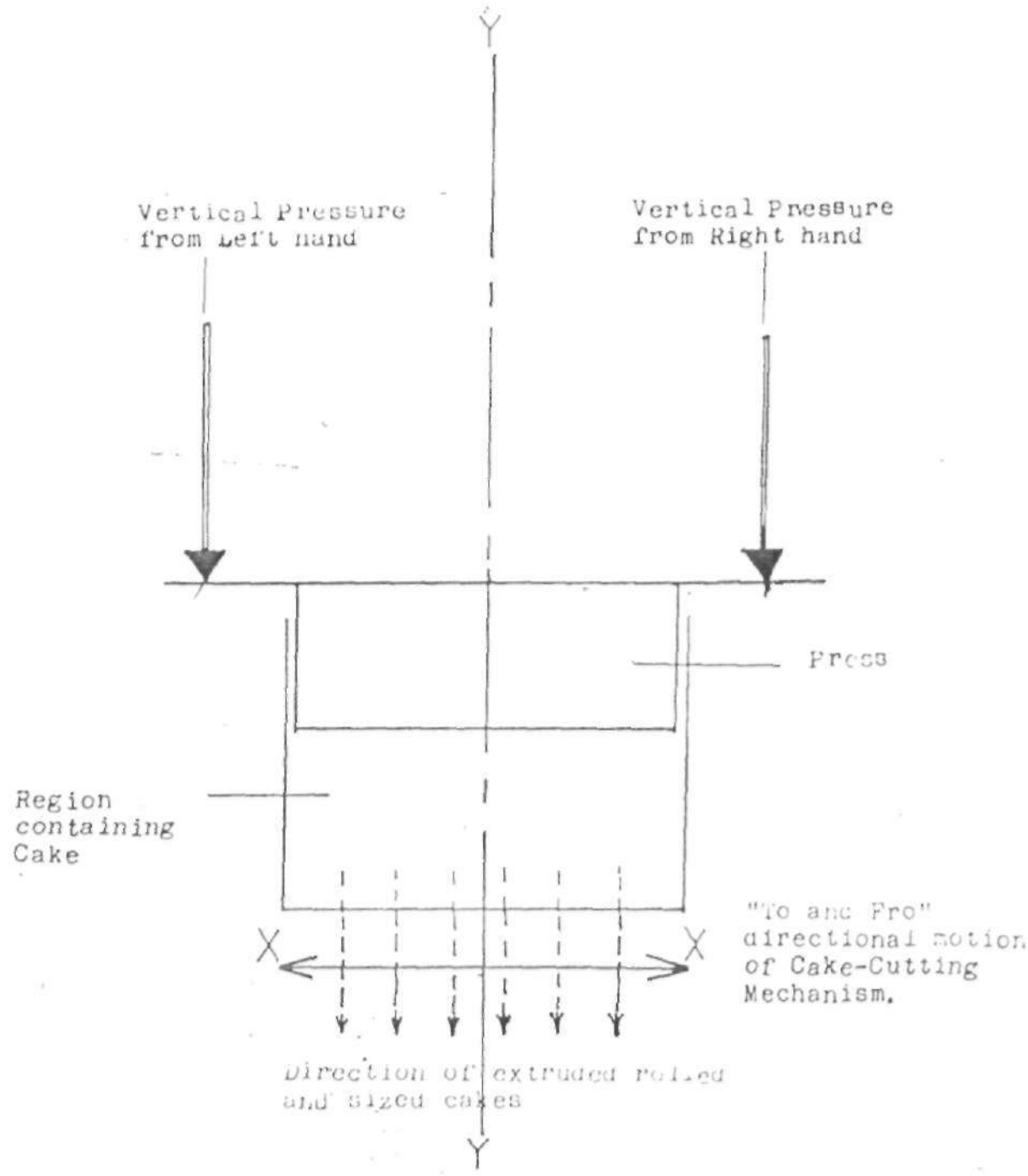


Figure 5.3 : Mechanics of Rolling And Cutting of Groundnut Groundnut Cake-Using the developed mechanism.

5.2 Evaluation of interventions

The evaluation studies were conducted to assess the performance of the interventions discussed in Chapter Five and also the optimum amount of water used in the kneading process. Results obtained were analysed and discussed as follows:

Detail description of evaluation of interzventions for different tasks is given below. For this comparison, three parameters were used. The studies carried out include the following:

5.2.1 Comparative Evaluation of Existing and Improved Kneading Tools

This was conducted from the perspective of energy, time and method studies. Additionally, the relationship between the quantity of groundnut and the amount of water used in the kneading process was also studied. An assessment of the oil extraction efficiency of the tools was also made.

Procedure

Firstly, the selected subjects were calibrated on the Hand Ergometer under a simulated physiological condition in the laboratory. Each of the subjects was made to crank the ergometer at an average rotational speed of 100 rpm determined by a tachometer for different weights, which range form 5 N to 50 N. A continuous cranking period of three minutes and resting allowance of six minutes was

... ng (three tiers) respectively. These

allowed each subject for each weight. The heartrates of the subjects were measured before and immediately after each cycle of cranking action, using the stethoscope and stop watch. The stethoscope picked the heartbeat of the subject through its sensitive membrane to the ear. The number of heartbeat was counted for a period of 15 seconds using the stopwatch. Afterwards the number of heartbeat obtained was multiplied by four to obtain the subject's heartrate. The corresponding energy expenditure in overcoming the frictions generated by the respective weights used in the calibration were calculated for each subject using equation (7). A calibration graph showing the linear relationship between change in heartrate and energy expenditure was then plotted for each of the three subjects.

Secondly, the three subjects; A, B, and C, were prepared psychologically on how to operate a newly designed Rotary Kneader and the existing IAR Modified Pestle. A 3-way factor, one observation per cell, experimental design layout was drawn as shown in appendix 3. Depending on the parameter for evaluation, the design can be interpreted as a Random Block Design with one factor as a replicate, or a 3 x 3 x 3 factorial design with fixed effects (Scheffe, 1959).

The subjects were then made to operate each of the three kneading tools under consideration for fixed groundnut quantities of 2.2 kg (one tier), 4.4 kg (Two tiers), and 6.6 kg (three tiers) respectively. These

weights are representative of those used by traditional processors in practice. Their operational time, heartrates and total rest durations during task were recorded. Additionally, the weights of oil extracted, both at the primary and final stages, as well as those of water added and fried cake (kulikuli) were also measured, using a weighing scale. These measured quantities and parameters are given in tables under appendix 4.

Plates (6), (7) and (8) show the subjects engaged in the kneading operation, using the traditional pestle, IAR Modified Pestle, and Rotary Kneader respectively. The same groundnut variety (appendix 2) was used by all the subjects. The moisture content of the groundnuts was also determined by drying samples in the Oven. Sieve analysis of the groundnut paste obtained from the conventional grinding mill was also conducted using the Can Sieves, in order to establish the range of average particle size of grind. Environmental parameters, such as temperature (wet and dry) was recorded and the corresponding relative humidities were determined.



Plate 6a: Kneading with Traditional Pestle (Pounding Action)



Plate 6b: Kneading with Traditional Pestle (Stirring and Lifting Actions)



Plate 7: Kneading with IAR Modified Pestle



Plate 8: Kneading with Developed Mechanism

5.2.2 Performance Evaluation of Developed "Cake Rolling and Cutting" Mechanism Against Hand Method

This was basically a time study. The time taken to press, roll and shape, as well as cut cake into sizes is determined for both the developed mechanism and Hand Method, under same physiological conditions. The quality of cut and ability to standardize the size of cut was also assessed. A one-way experimental design was used.

Procedure

For each trial, two subjects were given the same quantity of cake (meal). One was made to use a newly designed Cake-Roller Press whilst the other adopted the Hand Method in rolling, sizing and finally cutting the cake. The subject using the Cake-Roller Press was helped in gaging the correct size of the extruded (rolled) cake before cutting them off with the mechanisms cutting unit. Total time taken by each subject to complete the task was recorded. The procedure was repeated again using the same quantity of groundnut per method and the time recorded.

Due to the small feed capacity of the model mechanism, cake obtained from 2.2 kg (one tier) of groundnut was used for each method per trial. Plate (4) shows the two subjects performing the shaping and cutting task using the hand rolling method and the Cake-Roller Press.



Plate 9: Shaping, Sizing and Cutting of Cake with Roller Press (Right), and with hand (Left)

5.2.3 Comparative Study on Performance of Improved and Existing Deskinning Apparatus

This was basically a work study to examine tools compatibility with the operators. Aspects studied included tool operational posture, ease of collection of products at end of task, mode of discharge of skins from the desired product, and time taken to complete the task. A one-way experimental design was used.

Procedure

Same quantities of roasted groundnut were deskinned using the existing IAR Deskinner, on one hand, and the Improved IAR Deskinner, on the other. The time taken to complete the task with each apparatus was recorded and the procedure was repeated again.

The complete task involved the rubbing of the groundnut using the apparatus and separating the skins from the deskinned groundnut by winnowing process. Quantity of groundnut used for each tool per trial was 2.2 kg (one tier). Plate (10) shows a subject operating with the existing IAR Deskinner whilst Plate (11) shows another subject using the Improved IAR Deskinner.



Plate 10: Deskinning with Existing IAR Groundnut Deskinner



Plate 11: Deskinning with Improved IAR Groundnut Deskinner in a Standing Posture



Plate 11: Deskinning with Improved IAR Groundnut Deskinner in a Standing Posture

5.2.4 Strength Test for Developed Kneading Mechanism and its Components

Most mortar's cannot contain more than 8.8 kg (four tiers) of groundnut when one-third of their volume is left empty for effective kneading. To study behaviour of the rotary kneading system for this quantity of groundnut, a trial was conducted. This was aimed, among others, to evaluate the resulting effect of the high level of friction to be overcomed by the mechanism's components, especially the fingers on the rings, and the torque plate fixture.

Procedure

Groundnut paste from 8.8 kg (four tiers) of grinded groundnut was kneaded using the Rotary Kneader. A pre-determined weight of water was used, and the time taken to complete the task was noted. Afterwards, a thorough examination of all units and components of the mechanism was conducted for any sign of weakening and/or breakage.

5.2.5 Evaluation of Groundnut-oil Processing Systems

The groundnut-oil extraction system was divided into three different forms. These are:

(a) the traditional system (S_1);

(b) the traditional system using IAR developed tools (S_2);

(c) extraction system using some traditional and IAR developed tools, as well as intervention for kneading, deskinning and cake rolling.cutting operations (S_3).

Table 6.1 gives detail of tools used for each system for different tasks.

TABLE 5.2: DESCRIPTION OF TOOLS FOR DIFFERENT SYSTEMS OF GROUNDNUT-OIL EXTRACTION.

No.	TASK	SYSTEM TOOLS ADOPTED		
		S_1	S_2	S_3
1.	Roasting	Pan	Pan	Pan
2.	Deskinning	Bag and stone	IAR Deskinner	Improved IAR Deskinner
3.	Grinding	Disc Mill	D Mill	Disc Mill
4.	Kneading	Ordinary Pestle	IAR Pestle	Rotary Groundnut Kneader
5.	Rolling/ Cutting	Hand	Hand	Cake-Roller Press
6.	Frying	Pan	Pan	Pan

Procedure

Each of the systems outlined in table 6.1 is applied in processing the given quantities of groundnut from the beginning to the end. For each system, the process of oil extraction is applied to groundnut quantities of 2.2 kg (one tier), 4.4. kg (two tiers) and 6.6 kg (three tiers). At the end of each system trial, the following parameters were determined and recorded: operational time; energy requirement; cake and oil quantities; and cost of use of system.

CHAPTER SIX

RESULTS AND DISCUSSION

6.1 Calibration of Subjects

Calibration graph relating heartrate change (concept proposed by Grandjean, 1988) and energy expenditure plotted for subjects A, B and C are shown by Figures 6.1, 6.2 and 6.3 respectively. The raw calibration data are given in Appendix 1.

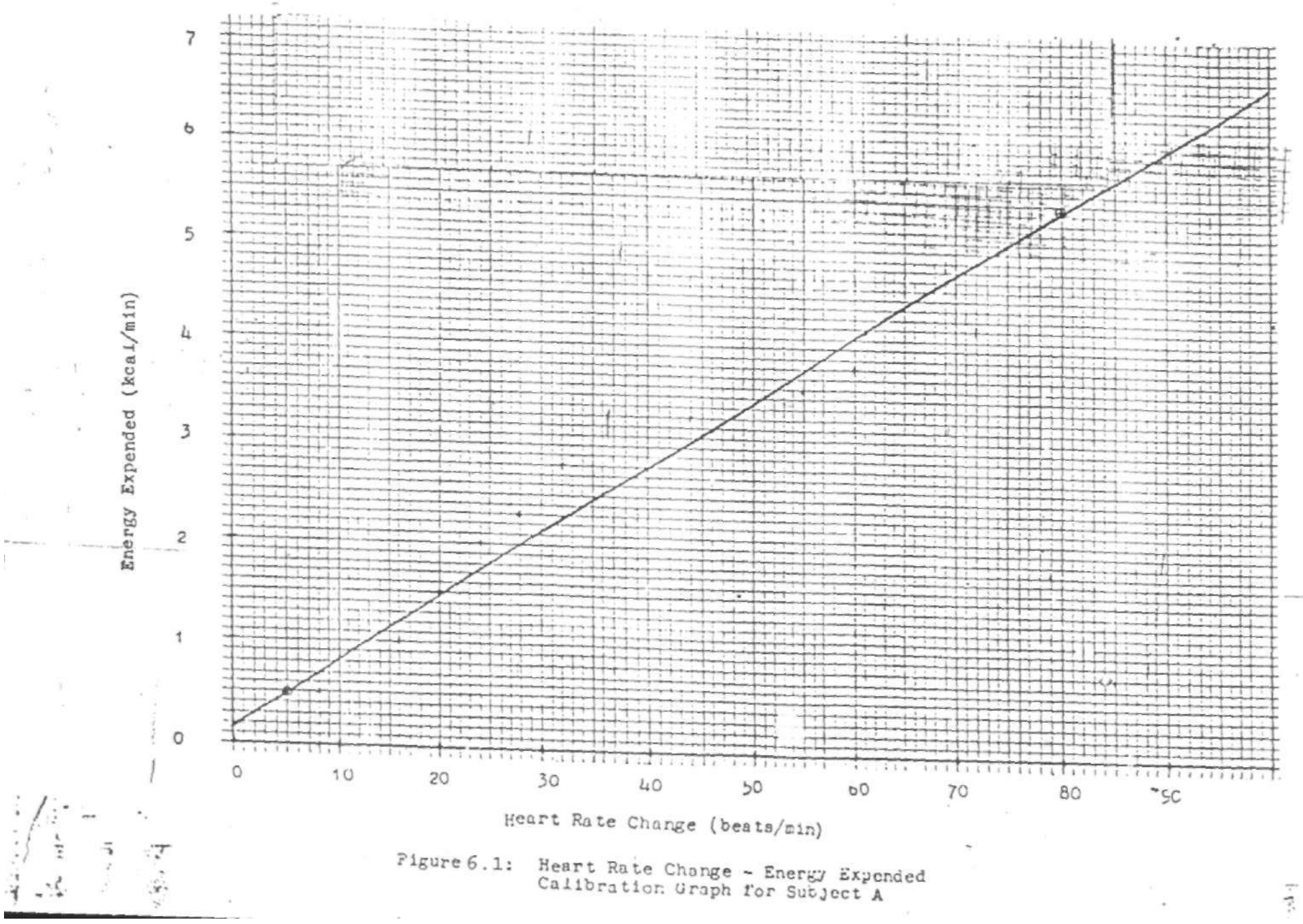


Figure 6.1: Heart Rate Change - Energy Expended Calibration Graph for Subject A

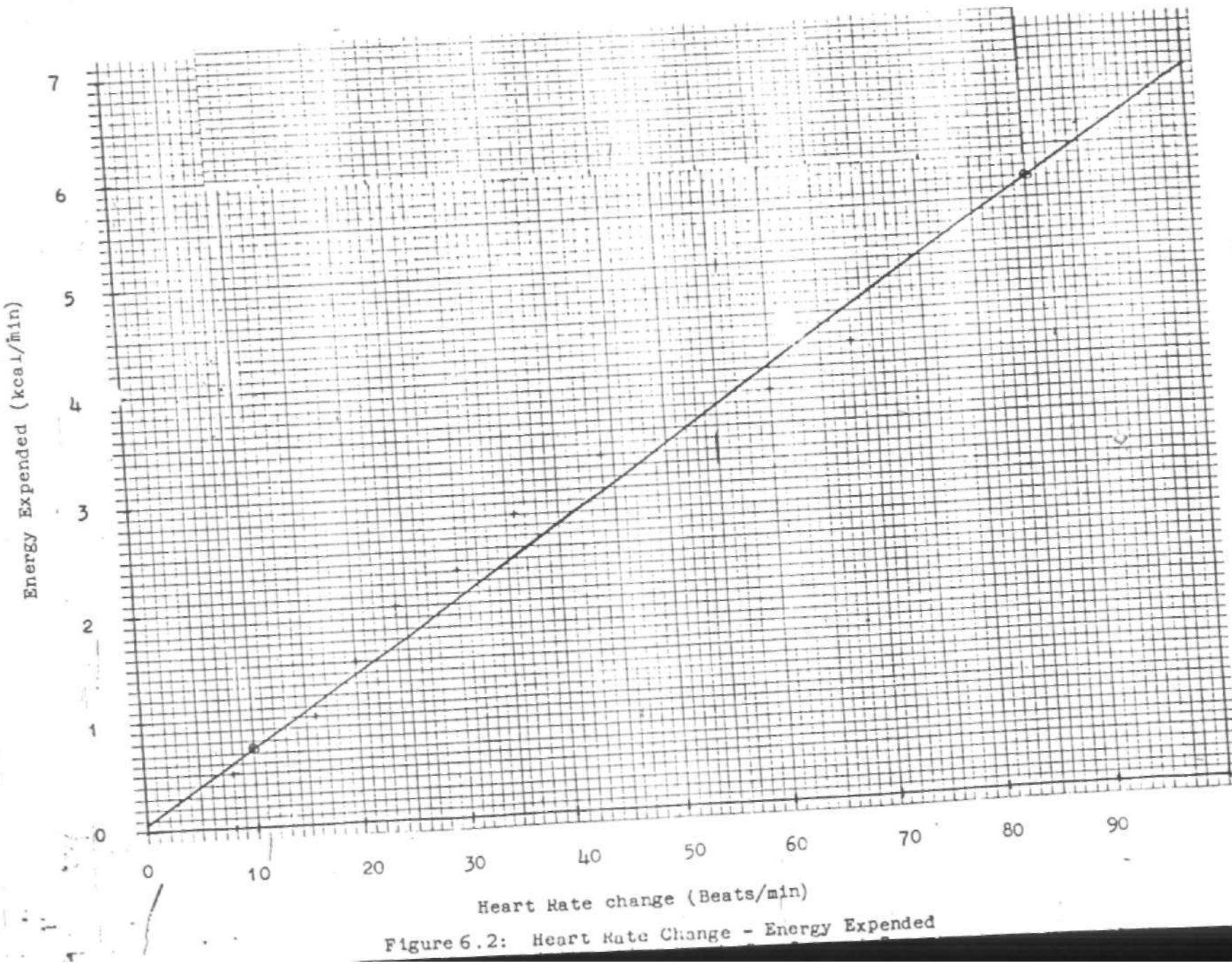


Figure 6.2: Heart Rate Change - Energy Expended

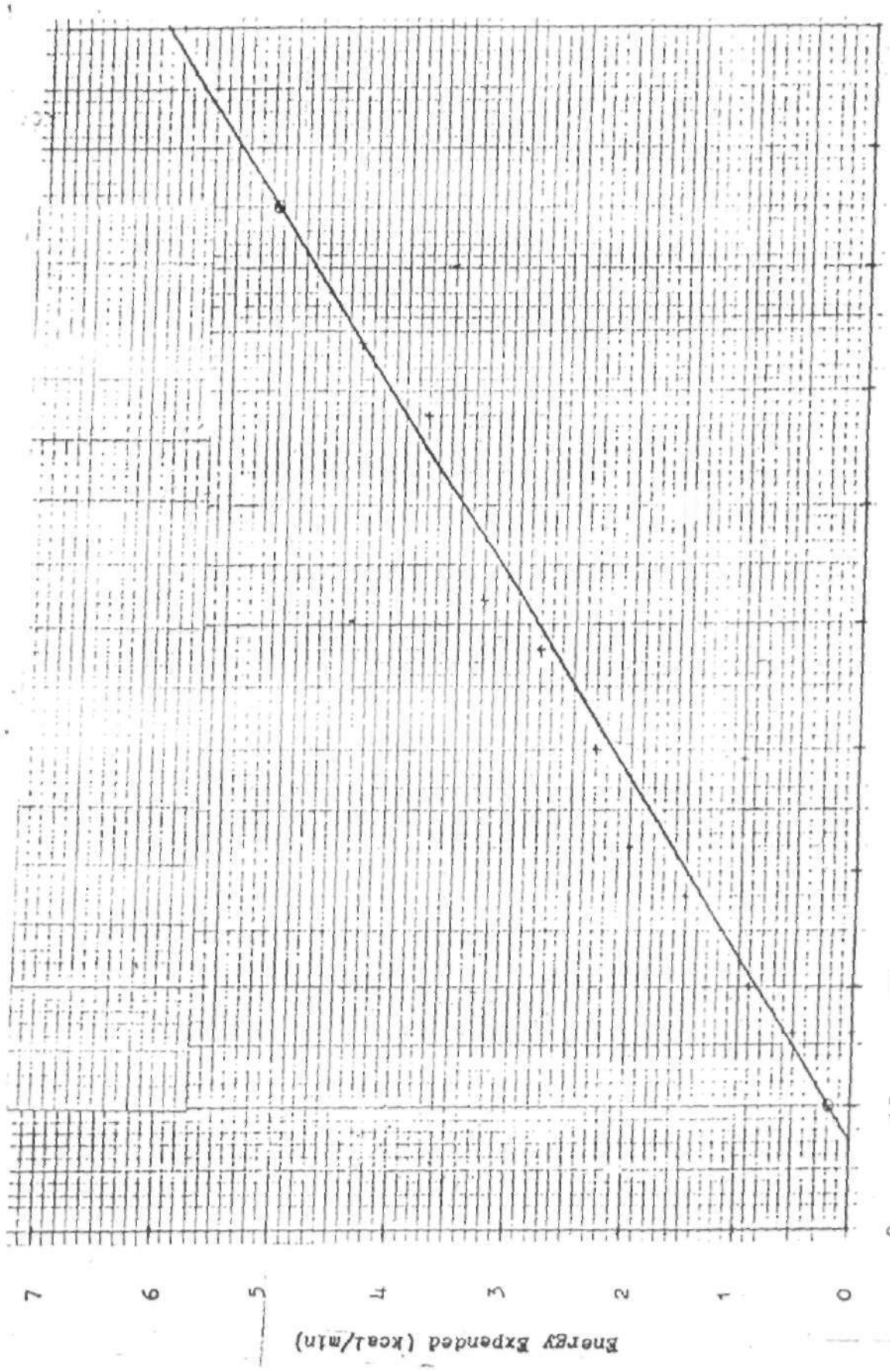


Figure 6.3: Heart Rate Change - Energy Expended Calibration Graph for Subject C

Table 6.1: RESULTS FROM STATISTICAL COMPUTATIONS ON RELATIONSHIP BETWEEN HEARTRATE CHANGE AND ENERGY EXPENDITURE FOR SUBJECTS

Subject -	Correlation Coefficient Between E and ΔH (r)	Degree of Association Between E amd ΔH (t values)	Regression Equation for E and ΔH
A	+0.955	9.107	E = 0.063 ΔH +0.17
B	+0.969	11.093	E = 0.066 ΔH +0.09
A	+0.978	13.260	E = 0.066 ΔH -0.46

From tables, t 0.05, 8DF = 2.306.

Correlation and Regression analysis of the calibration data for the respective subjects, summarized in table 6.1, indicated that the relationship between heartrate change and Energy expenditure is linear. This is supported by the strong positive correlation coefficient values obtained for the ΔH - E relationship for each subject. The strength of the ΔH - E relationship was further indicated by the results of the significance test (t - test) for the calculated r - values. The fact that t calculated > t table for all the r - values shows a high level of significance between ΔH and E. This means that a high degree of association exist between Energy Expenditure and Heartrate Change. Hence the use of the heartrate change as the physiological index (Grandjean, 1988) appears to be in order.

With respect to the linear regression equations linking E and ΔH, further mathematical analysis will show that, for E = 0, ΔH will be negative from equations for subject A and subject B. Negative ΔH will be unrealistic. Thus by computing the averages of the regression

coefficients and regression constants, a general equation linking E and ΔH can be established:

i.e. Average Regression Coefficient = 0.065

0.07

Average Regression Constant = 0.066

≃ 0.07

Hence a general linear regression equation for the three subjects can be written as:

$E = 0.07\ \Delta H - 0.07$; or $E = 0.07\ (\Delta H - 1)$

6.2 Comparative Evaluation of Kneading Tools

A summary of results for the time and energy studies conducted on the respective tools are given in Table 6.2 below:

Table 6.2: SUMMARY OF RESULTS FOR KNEADING TOOLS COMPARATIVE EVALUATIONS

Kneading Tool	Quantity (Tier, @ 1 Tier = 2.2 kg)	Kneading Time (minutes)			Energy Expended (kcal/min)			Estimated Production Cost (₦)
		A	B	C	A	B	C	
Traditional Pestle	1	23	24	31	1.75	1.10	0.30	100-150
	2	30	17	19	2.50	1.65	0.60	
	3	22	24	26	3.05	2.20	1.10	
IAR Modefied Pestle	1	23	31	21	1.20	1.10	0.60	1,300
	2	42	32	24	2.25	2.20	0.85	
	3	34	41	45	2.50	3.00	0.85	
Rotary Groundnut Kneader	1	20	30	30	0.70	1.65	0.00	1,500
	2	29	29	47	2.25	2.45	0.65	
	3	20	22	39	2.00	1.40	0.60	

The raw data are given in appendix 4. A summary of the F - values obtained from the analysis of variance for subjects, groundnut quantities and kneading tools, for both time and energy parameters is given by table 6.3 below:

Table 6.3: SUMMARY OF CALCULATED F - VALUES FROM ANOVA TABLES (APPENDIX 5) FOR TIME AND ENERGY EXPENDITURE

Variation	DF	F - Values	
		Kneading Time T	Energy Expended E
Tools (T)	2	6.403 *	2.115
Quantity (Q)	2	1.893	17.038 **
Subjects (R)	2	2.039	40.962 ***
T x Q	4	3.416	1.654
T x R	4	3.762	1.692
Q x R	4	2.592	-

***Very Highly Significant; ** Highly Significant; * Significant

Based on the results in table, the following deductions could be made on the kneading time and energy expenditure parameters.

6.2.1 Energy Expenditure

Results from the analysis of variance for energy expenditure indicates a very significant variation at the 5% significance level on the energy expended among the subjects and quantity of groundnut kneaded.

The energy expenditure among the subjects, (RA, RB and RC), each using the same tool and quantity shows a variation in the order

$$E_{RA} > E_{RB} > E_{RC}$$

for all the tools. On the other hand, the average energy expenditures by the subjects, with respect to the respective tools, could be established as follows:

(a) for subject A:

$$E_{TRADITIONAL} > E_{IAR} > E_{DEVELOPED}$$

(b) for subject B:

$$E_{IAR} > E_{DEVELOPED} > E_{TRADITIONAL}$$

(c) for subject C:

$$E_{IAR} > E_{TRADITIONAL} > E_{DEVELOPED}$$

On the average, the variation for all the subjects could be deduced as follows:

$$E_{IAR} \simeq E_{TRADITIONAL} > E_{DEVELOPED}$$

The variation in the energy expended to knead respective (Q) quantities is established to be in the order

$$Q_1 < Q_2 < Q_3$$

which was obvious since the three quantities are linked by weight factor.

i.e. $Q_3 = 3\ Q_1$

$Q_2 = 2\ Q_1$

$Q_3 = \frac{3}{2}\ Q_2$

With respect to energy variation among the different tools, the following can be deduced for same quantity kneaded:

(a) *for one* "tier" (Q_1),

$$E_{TRADITIONAL} > E_{IAR} > E_{DEVELOPED}$$

(b) for two "tiers" (Q_2)

$$E_{TRADITIONAL} > E_{IAR} \simeq E_{DEVELOPED}$$

(c) for three "tiers" (Q_3)

$$E_{TRADITIONAL} \simeq E_{IAR} > E_{DEVELOPED}$$

Averagely, the energy expended in kneading a given quantity of groundnut paste varies, depending on the type of tool used. This slight variation is viewed to be statistically insignificant. The order of variation could be given as follows:

$$E_{TRADITIONAL} > E_{IAR} > E_{DEVELOPED}$$

6.2.2 Kneading Time

Results from the analysis of variance for continuous kneading time indicated a significance variation at the 5% significance level among the tools. This variation, with respect to the tools for different quantities of paste kneaded, could be established in the following order:

(a) for one "tier"

$$T_{TRADITIONAL} < T_{IAR} < T_{DEVELOPED}$$

(b) for two "tiers"

$$T_{TRADITIONAL} < T_{IAR} < T_{DEVELOPED}$$

(c) for three "tiers".

$$T_{TRADITIONAL} < T_{IAR} \simeq T_{DEVELOPED}$$

On the average, the general time variation can be established as follows:

$$T_{TRADITIONAL} < T_{IAR} < T_{DEVELOPED}$$

On the other hand, by comparing the working time ranges per quantity for the respective tools, the minimum kneading time variations are as follows:

(a) for one "tier"

$$T_{TRADITIONAL} > T_{IAR} > T_{DEVELOPED}$$

(b) for two "tiers"

$$T_{DEVELOPED} > T_{IAR} > T_{TRADITIONAL}$$

(c) for three "tiers"

$$T_{IAR} > T_{TRADITIONAL} > T_{DEVELOPED}$$

Generally, the minimum kneading time could be deduced from the variations as follows:

$$T_{DEVELOPED} < T_{TRADITIONAL} < T_{IAR}$$

Further observations made on the operation of the developed Rotary Kneader revealed that the kneading time was influenced, primarily by two factors. These are the level of friction to be overcomed in moving through the paste, and the operator's choice of operational speed. Thus with one "tier", it was established that an average operational speed of 100 rpm completes the task in 11 minutes. Using two "tiers", a time of about 20 minutes was

obtained. With four "tiers" (kneading by three operators), the task was completed in 20 minutes.

The time variation, with respect to maximum kneading time was obtained as follows:

(a) for one "tier"

$$T_{DEVELOPED} < T_{TRADITIONAL} \simeq T_{IAR}$$

(b) for two "tiers"

$$T_{TRADITIONAL} < T_{IAR} < T_{DEVELOPED}$$

(c) for three "tiers"

$$T_{TRADITIONAL} < T_{DEVELOPED} < T_{IAR}$$

The time variation in kneading the different quantities could be attributed to the following factors:

(1) increase in quantity implies an increase in mass and volume of paste to be kneaded. This increase in volume of paste causes an increase in its surface contact area with the tools. Hence as the paste gets harder during kneading, the motion resistance forces on the tool also increases;

(2) since an increase in quantity results in an increase in motion resistance, the operators' ability to move the tool inside the hardened paste is reduced. Hence the greater time used in kneading increasing quantities.

The time variation analysis indicated above could be deceptive. This is so when one takes into account the fact that the operators using the traditional and IAR modified pestles received some assistance during the task. The assistance was offered by "help-hands" who held the mortars to keep them steady. Thus the operators kneading time, as given in Table 4.6, was only for the period used in turning the paste. Consideration was not given to time used in steadying mortar. For the Rotary Kneader, the operators worked alone using their legs to steady the mortar when required. Also, operators using the IAR modified pestle and the traditional pestle tend to stop the task immediately oil is produced. This was observed to be due to exhaustion. With respect to the Rotary Kneader, the suitability of its operational method and posture appears to make its operation easier. This factor tends to make the operators prolong their operational time with the belief that more entrapped oil could be released to increase expected quantity.

6.2.3 Tools' Oil Extraction Efficiencies (eff)

The efficiency of oil extraction by the tools were calculated from the relation:

$$\text{eff} = \frac{\text{\% oil extracted by Tool}}{\text{\% Oil content of groundnut variety used}}$$

The percent oil content of groundnut variety used is given in Appendix 2, whilst the percent oil extracted by each tool type are given in Appendix 4.

Table 6.4 below gives the range of oil extraction efficiencies of the Tools respectively.

Table 6.4: OIL EXTRACTION EFFICIENCY RANGES FOR TOOLS

Quantity of GROUNDNUT (kg)	EFFICIENCY RANGE PER TOOL (eff)		
	Traditional Pestle	IAR Modified Pestle	Developed Mechanism
2.2	0.6 - 0.8	0.1 - 0.7	0.6 - 0.7
4.4	0.6 - 0.7	0.5 - 0.7	0.5 - 0.9
6.6	0.5 - 0.7	0.4 - 0.7	0.6 - 0.7

A summary of the F - values from the analysis of variance of the raw data (Appendix 5) are given in table 6.5 below. The complete ANOVA Table is given by Table A5.7 in Appendix 5.

Table 6.5: SUMMARY OF ANOVA TABLE for Oil Extraction Efficiency

VARIATION		DF	F - VALUE	
Tool	(T)	2	1.10	NS
Quantity	(Q)	2	0.20	NS
SUBJECT	(R)	2	0.80	NS
	T x Q	4	0.20	NS
	T x R	4	1.32	NS
	Q x	4	1.12	NS

NS = not significant.

Results obtained from the ANOVA indicated that the variation in the tools' oil extraction efficiencies is not significant at the 5% significance level. Yet, comparison of the efficiency ranges given in table 6.4 indicates some slight variations among the tools. These variations might be considered as relevant with respect to tool performances. Comparison of the maximum oil extraction efficiencies of the tools for each quantity of groundnut from the given ranges resulted in the following order.

(a) for 2.2 kg:

$$eff_{TRADITIONAL} > eff_{IAR} = eff_{DEVELOPED}$$

(b) for 4.4 kg:

$$eff_{DEVELOPED} > eff_{TRADITIONAL} = eff_{IAR}$$

(c) for 6.6 kg:

$$eff_{DEVELOPED} = eff_{TRADITIONAL} = eff_{IAR}$$

Explanation for the slight variations in the oil extraction efficiencies with respect to different quantities could be linked with the following factors:

(1) ability of tool to overcome increased motion resistance with increased quantity of paste. Lesser quantity implies smaller motion resistance and hence thorough kneading and higher oil extraction;

(2) increased exhaustion rate on operators with the increase in motion resistance on tool.

This reduces the operators ability to perform complete kneading in order to free oil entrapped in cake clots. Hence the reduction in extraction efficiency, with increasing quantity.

Assessing individual tool performances for specific quantities, the following observations were made:

(1) The slightly higher average extraction efficiency of the traditional pestle over the others, for one tier of groundnut, could be related to the additional pounding action during the kneading operation. This action helps in crushing additional oil molecules for the release of more oil. But for quantities ranging from two "tiers" and above, the pounding action tends to lose any advantage of effective crushing. The increased quantity of paste tends to cushion the pounding impact, especially when the paste gets hardened.

(2) The relatively higher extraction efficiency exhibited by the Rotary Kneader, on the average, for quantities of two and three tiers was due to its ability to overcome the increased level of motion resistance. This could be attributed to the cutting and pulverizing action of its knife-edged fingers on clotted cake. Hence entrapping of "free" oil molecules and partially-free oil molecules in the clotted cake is reduced. This

ensures an increase in the quantity of oil extracted.

6.3 Quantification of the Amount of Water Used in Kneading Process

A summary of the amount of water used by the subjects in the kneading process are given in Table 6.6 below:

Table 6.6: A SUMMARY OF AMOUNT OF WATER USED BY SUBJECTS IN KNEADING PROCESS

KNEADING TOOLS	GROUNDNUT QUANTITY (Tier(@ 2 tier= 2.2kg	WEIGHT OF WATER ADDED/SUBJECT (kg)		
		A	B	C
Traditional Pestle	1	0.60	0.50	0.70
	2	1.20	1.10	1.00
	3	1.30	1.50	1.50
IAR Modified Pestle	1	0.70	0.60	0.60
	2	1.10	1.00	1.00
	3	1.70	1.50	1.50
Rotary Kneader	1	0.50	0.50	0.60
	2	1.00	1.10	1.20
	3	1.80	1.40	1.40

Table 6.7 and 6.8 give summaries of the results from ANOVA and regression analysis respectively. (Details given in Tables A5.8 and A5.9-11 of Appendix 5).

Table 6.7: SUMMARY OF CALCULATED F - values

SOURCE OF VARIATION	DF	F - value
Tool (T)	2	0.238
Quantity (Q)	2	91.428***
Subject (R)	2	0.714
T x Q	4	0.476
R x R	4	0.238
Q x R	4	0.238

Table 6.8: RESULTS FROM STATISTICAL COMPUTATIONS ON RELATIONSHIP BETWEEN GROUNDNUT QUANTITY (Y) AND AMOUNT OF WATER USED (X)

KNEADING TOOL	CORRELATION COEFFICIENT BETWEEN X AND Y (r)	DEGREE OF ASSOCIATION BETWEEN X AND Y (t - values)	REGRESSION EQUATION FOR X AND Y
Traditional Pestle	+ 0.992	20.790	Y = 0.195 X + 0.217
IAR Modified Pestle	+ 0.993	31.402	Y = 0.25 X + 0.045
Rotary Kneader	+ 0.992	20.790	Y = 0.24 X + 0.039

(1) From Statistical Tables, t 0.05, 8 DF = 2.306

(2) X in kg and Y in "tiers"

Averagely, table 6.9 below shows the general relationship between groundnut quantity and amount of water used or required for the kneading operation.

Table 6.9: GENERAL RELATIONSHIP BETWEEN GROUNDNUT QUANTITY AND AMOUNT OF WATER REQUIRED

QUANTITY OF GROUNDNUT, Y (Tiers)	AVERAGE WEIGHT OF WATER REQUIRED, X (kg)
1	0.6
2	1.1
3	1.6

Regression analysis of the data in table 6.9 resulted in the following general linear regression equation:

$$X = 0.5\ Y + 0.1 \quad - \quad (i)$$

where $Y \geq 1$, in tiers, and X in kg.

Based on experimental standardization,

1 tier ≡ 2.2 kg

approximating to the nearest kilogram,

1 tier ≃ 2 kg

or ½ tier ≃ 1 kg

Thus, a quantity, Y in tiers, can be converted to kg

i.e. Y, in kg ≡ Y/2, in Tiers

Hence, equation (i) can also be re-written by converting Y from tiers to kg, as follows:

$$X = 0.25\,Y + 0.1 \quad \ldots\ldots\ldots\ldots \text{(ii)}$$

where both X and Y are in kilograms.

In general, the relationship between amount of water used and the quantity of groundnut to be kneaded could be represented simply as follows:

$$X = 0.25\,Y \quad \ldots\ldots\ldots \text{(iii)}$$

for Y in kg, and X in kg).

Results from the ANOVA established that the variation in the amount of water used with respect to groundnut quantity is very significant at the 5% significance level. As such, the order of variation of the quantities could be established as follows:

$$Q_3 > Q_2 > Q_1$$

Also, the absence of tool influence on the amount of water used, as established in table 6.7 appeared to be backed by the closeness of the correlation coefficients calculated for each tool. The higher values of r, as indicated in table 6.8, show a high positive correlation

between groundnut quantity and weight of water used. A further significance test also established a strong association between the two parameters since t calculated > t table.

Regression analysis on the average values of water used for respective quantities also established a linear regression relationship between the groundnut quantity and weight of water used in kneading.

By averaging the weight of water used per groundnut quar' ty, for all the tools, a simple general linear relationship was evolved as indicated in table 6.9. Further regression analysis on these average values for water and groundnut quantity resulted in the general linear regression equations given in equation (iii). These general linear equations fairly relate the amount of water required (X) for a given quantity of groundnut (Y) to be kneaded.

Miscellaneous tests conducted to investigate the practical effectiveness of equations (iii for quantities ranging from 2.2 kg to 8.8 kg proved positive. Estimated weights of water used in the kneading operations satisfied the practical requirement for the respective weights of groundnut paste kneaded. Also, a thorough examination of the Rotary Groundnut Kneader, after the strength test, showed t' at neither the mechanism nor any of its component indicated any sign of breakage or weakening.

6.4 Performance evaluation of Improved IAR Groundnut Deskinner

Evaluation of the operational performance of the IAR groundnut deskinner apparatus resulted in the following:

i) The improved design eliminated the operational posture problem associated with the existing design, as indicated in table 4.1b;

ii) The skins separated from the nuts, during the rubbing operation discharge simultaneously through the sieves. At the end of task, amount of undischarged skins remaining in the deskinned nuts are relatively smaller when compared to a case where the old or existing IAR deskinner is used;

iii) At the end of operation, the deskinned groundnuts are collected in a container placed below the apparatus gate. This was done by sweeping off the nuts with the hands. It appeared easier and more comfortable when compared to the case of lifting the entire apparatus off the ground before the nuts could be transferred into a container, as was the case with the existing IAR Deskinner;

iv) Due to the simultaneous discharge of the skins as they are removed from the groundnuts, the collected deskinned nuts required minimal

winnowing (Table 6.10) when compared to the existing apparatus. The existing deskinner tend to require extensive winnowing after the rubbing operation, in order to separate the removed skins from the deskinned nuts.

v) Table 6.10 below gives the average operational time comparison between the improved deskinner and the existing deskinner, using quantities of one "tier" per apparatus per cycle. (Raw data given in appendix A4.10).

Table 6.10: OPERATIONAL TIME COMPARISON BETWEEN IMPROVED AND EXISTING APPARATUSES

IAR DESKINNER	AVERAGE OPERATIONAL TIME (PER TIER) (minutes)		
	RUBBING OPERATION	WINNOWING OPERATION	TOTAL
Improved	2.0	0.5	2.5
Existing	3.0	2.0	5.0

v) Production cost wise, the only difference between the two apparatuses was that of manufacturing the leg support in the improved apparatus.

Table 6.11: SUMMARY OF ANOVA TABLE (TABLE A5.12) DESKINNER EVALUATION. (Appendix A5.12)

VARIATION	DF	F - VALUE
Tool	1	4664.18 ***

*** Very highly significant

Objective analysis of the results outlined in table 6.11 showed that the variation in the operational time between the Improved IAR deskinner and the existing apparatus is very highly significant. Comparison of their mean operational time (table 6.10) showed a better performance with the improved apparatus. Thus usage of the improved apparatus resulted in cutting the operational time in the deskinning process by half, or 50 percent.

Generally, the provision of the suitable working height to the existing apparatus to form the improved version resulted in improved operator-tool interaction. It also resulted in the winnowing process being virtually eliminated.

6.5 Performance Evaluation of Groundnut Cake-Roller Press

Operational time comparison between the developed mechanism and the hand method resulted in the following:

(a) Using the mechanism, the cake was shaped, rolled and cut without any direct contact with the hand. The converse was the case with the hand method.

(b) Table 6.12 below shows the comparative operational time for the two modes of operation per operator. (Raw data given in appendix A4.11)

Table 6.12: OPERATIONAL TIME COMPARISON BETWEEN MECHANISM AND HAND ROLLING METHOD

TOOL FOR CAKE ROLLING AND CUTTING	AVERAGE OPERATIONAL TIME PER TIER (minutes)
Cake-Roller Press	10
Hand	26

(c) Diameter of rolled cake from Cake-Roller Press standardized. Averagely, 20 rolled cakes are produced and cut simultaneously with each press. These rolled-and-cut cakes have the same size. With respect to the hand method, only one long roll (about 30 cm long) can be produced at a time. The size of each cut varies from another.

Table 6.13 **SUMMARY OF ANOVA TABLE (TABLE A5.13) FOR CAKE ROLLING AND CUTTING EVALUATION (Appendix A5.13)**

VARIATION	DF	F - VALUE
Tool	1	1439.82 ***

*** Very highly significant

Results in table 6.13 showed that the variation in the operational time between the use of Hand and the Cake-roller Press is very highly significant. Comparison of their mean operational time (table 6.12) showed a better performance with the Cake-roller Press.

On analyzing these results and observations, it was realized that the use of the Cake-Roller Press, though a model, reduced the task duration by 16 minutes. Also, production of cake-rolls with same diameter by the mechanism gave it an advantage over the usage of hand, in terms of standardization. The higher time required to complete the task using hand could be related to the operator having to judge the appropriate roll diameter of the cake and size of each cut by intuition. Though

operators using the Cake-Roller Press received assistance in gaging the correct length of extruded cake, the fact that it reduced the existing operational time by more than 60 percent makes it more efficient. Additionally, the virtual elimination of hand contact in the rolling and cutting process shows an improvement in product quality control.

6.6 Systems Evaluation for Groundnut-oil Extraction

Results obtained from the evaluation of the three systems of groundnut-oil extraction, namely, those using only traditional tools (S_1), those using traditional and IAR tools (S_2), and those using existing tools and interventions (S_3) are summarized in table 6.14 below. Also, the estimated operational cost for each system and the corresponding minimum energy expended are given in table 6.15. In the estimation of the system operational cost, a nominal labour charge of 40 Naira per hour was used. The costs listed in table 6.15 holds for actual working time only.

Table 6:14: SUMMARY OF RESULTS FOR THE DIFFERENT SYSTEMS OF OIL EXTRACTION

QUANTITY OF GROUNDNUT (kg)	SYSTEM USED	AVERAGE SYSTEM DURATION (minutes)	MINIMUM ENERGY EXPENDITURE (kcal/min)	AVERAGE WEIGHT OF OIL (kg)
2.2	S_1	106	1.05	0.53
	S_2	104	0.97	0.37
	S_3	81	0.78	0.47
4.4	S_1	181	1.58	1.07
	S_2	191	1.77	0.90
	S_3	177	1.78	0.90
6.6	S_1	262	2.12	1.37
	S_2	278	2.12	1.23
	S_3	240	1.33	1.47

Using data from table 6.14 above, the data in table 6.15 are obtained from the following relations:

(a) Minimum Energy Requirement = Minimum Energy Expenditure x Average System Duration

(b) System Operating Cost = Nominal Labour Charge x Average System Duration

Table 6:15 SYSTEM'S COST AND ENERGY REQUIREMENT

QUANTITY OF GROUNDNUT (kg)	SYSTEM USED	MINIMUM ENERGY EXPENDITURE (kcal)	OPERATING COST @ ₦40/hr OR ₦0.67/min (Naira)
2.2	S_1	110.38	70.40
	S_2	101.27	69.60
	S_3	63.18	54.00
4.4	S_1	286.30	120.80
	S_2	338.78	127.60
	S_3	315.06	118.00
6.6	S_1	555.86	174.60
	S_2	590.21	185.60
	S_3	319.20	160.00

Comparative analysis of the results in tables 6.14 and 6.15 indicated that systems output differed for each of the evaluation parameters. Systems variation, with respect to each parameter could be established as follows:

i) System assessment, with respect to average operational time (Table 6.14) for each of the quantities considered indicated that:

(a) for 2.2 kg

$$S_3 < S_2 < S_1$$

(b) for 4.4 kg

$$S_3 < S_1 < S_2$$

(c) for 6.6 kg

$$S_3 < S_1 < S_2$$

Hence it could be inferred, generally, that for any given quantity of groundnut to be processed, the system comprising the existing and intervention tools (S_3) is the most time efficient.

ii) assessment of systems, with respect to minimum energy requirement (Table 6.15) indicated that:

(a) for 2.2 kg

$$S_3 < S_2 < S_1$$

(b) for 4.4 kg

$$S_1 < S_3 < S_2$$

(c) for 6.6 kg

$$S_3 < S_1 < S_2$$

Generally, system consisting of existing tools and interventions seem to have the minimal energy requirement when compared to the other two systems. Hence system S_3 appears to be the most efficient and involves less drudgery.

iii) System assessment with respect to operational cost (Table 6.15) showed that:

(a) for 2.2 kg

$$S_3 < S_2 < S_1$$

(b) for 4.4 kg

$$S_3 < S_1 < S_2$$

(c) for 6.6 kg

$$S_3 < S_1 < S_2$$

In general terms, the system consisting of existing tools and interventions requires lesser operating cost, compared to the other two systems. System involving traditional and IAR tools tends to require a higher operating cost. Thus, system S_3 is the most cost efficient.

iv) System assessment, with respect to amount of oil obtained (Table 4.15) indicates that:

(a) for 2.2 kg

$$S_1 > S_3 > S_2$$

(b) for 4.4 kg

$$S_1 > S_3 = S_2$$

(c) for 6.6 kg

$$S_3 > S_1 > S_2$$

Generally, system consisting of existing tools and interventions seem to have the minimal energy requirement when compared to the other two systems. Hence system S_3 appears to be the most efficient and involves less drudgery.

iii) System assessment with respect to operational cost (Table 6.15) showed that:

(a) for 2.2 kg

$$S_3 < S_2 < S_1$$

(b) for 4.4 kg

$$S_3 < S_1 < S_2$$

(c) for 6.6 kg

$$S_3 < S_1 < S_2$$

In general terms, the system consisting of existing tools and interventions requires lesser operating cost, compared to the other two systems. System involving traditional and IAR tools tends to require a higher operating cost. Thus, system S_3 is the most cost efficient.

iv) System assessment, with respect to amount of oil obtained (Table 4.15) indicates that:

(a) for 2.2 kg

$$S_1 > S_3 > S_2$$

(b) for 4.4 kg

$$S_1 > S_3 = S_2$$

(c) for 6.6 kg

$$S_3 > S_1 > S_2$$

Generally, it could be inferred here that the system comprising of mainly traditional tools (S_1) results in higher oil output for small quantities of groundnut. On the other hand, the system comprising of existing tools and interventions (S_3) appears to result in higher oil output for larger quantities of groundnut.

Thus from the four assessment parameters considered, it could be inferred, generally, that the system comprising of existing tools and intervention is the most efficient to operate and affordable to maintain.

CHAPTER SEVEN

7.0. SUMMARY AND CONCLUSIONS

7.1.0 Summary

An ergonomic study was conducted on the traditional groundnut-oil extraction system with the aims of identifying those operations involving heavy drudgery, as well as those which are time consuming. The study was also aimed at evolving relevant design and/or operational mechanisms to eliminate or minimize those constraints associated with the oil extraction system, in order to maximize the productivity of the system.

The study was divided into three segments: a primary study, design and development and a secondary study. In the primary study, both method and time studies were undertaken on the entire operational system of traditional groundnut-oil processing. The observations made, as well as subjective comments from operators on the level of operational drudgery, and time were recorded. Additionally, the degree of tool - operator compatibility for respective tasks in the system were noted. In the design and development, improved tools were designed and developed, using anthropometric principles, for areas of intervention identified in the primary study. In the secondary studies, developed tools were evaluated against existing tools. Parameters used in the evaluation included energy expenditure, operatio. l time, operational posture and performance efficiency. Three subjects were used in the evaluation. Their energy expenditure was determined

indirectly from a calibration graph, matching heartrate difference (or rise) against energy expenditure. The primary study identified the kneading task to involve heavy drudgery. It also found the cake rolling and cutting task as time consuming whilst the groundnut deskinning tool provided operators with posture problem. The secondary study also established that the developed tools showed better performances compared to the existing tools.

7.2.0 Conclusion

Areas of constraints/intervention in the traditional groundnut-oil extraction system were identified from the ergonomic studies. Improved tools/methods developed using anthropometric principles removed the constraints identified with the kneading, deskinning as well as the cake rolling and cutting tasks. The better performances of the improved tools/methods compared to those of the existing ones indicated that the aim of upgrading the existing traditional system was achieved.

7.3.0 Recommendations

(1) Motorisation of the developed kneading mechanism should be pursued to further reduce energy requirement. This should be provided as an option to hand cranking.

(2) The developed cake rolling and cutting mechanism should be investigated for possible improvement.

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APPENDICES

APPENDIX 1

SUBJECTS CALIBRATION DATA

TABLE A1:1: CALIBRATION DATA FOR SUBJECT A

S/No.	Weight (kN)	Scale Reading (kN)	Average Crank Speed (RPM)	HEARTRATE, H (beats/min)			Energy* Expended (kcal)
				Final	*Initial*	*ΔH*	
1.	0.005	0.005	100	92	84	8	0.00
2.	0.010	0.005	100	96	88	8	0.50
3.	0.015	0.005	100	104	88	16	1.00
4.	0.02	0.005	100	108	88	20	1.50
5.	0.025	0.005	100	108	84	24	2.00
6.	0.030	0.007	100	112	84	28	2.30
7.	0.035	0.007	100	120	88	32	2.80
8.	0.040	0.007	100	132	88	44	3.30
9.	0.045	0.007	100	152	92	60	3.80
10.	0.050	0.008	100	164	92	72	4.20

* Calculated (in kJ) using equation (7) and converted to kcal.

TABLE A1:2: CALIBRATION DATA FOR SUBJECT B

S.No	Weight (kN)	Scale Reading (kN)	Average Crank Speed (RPM)	HEARTRATE, H (beats/min) Final	Initial	ΔH	Energy* Expended (kcal)
1.	0.005	0.005	100	88	80	8	0.00
2.	0.010	0.005	100	92	84	8	0.50
3.	0.015	0.005	100	108	92	16	1.00
4.	0.020	0.005	100	112	92	20	1.50
5.	0.025	0.005	100	124	100	24	2.00
6.	0.030	0.007	100	124	96	28	2.30
7.	0.035	0.007	100	124	88	36	2.80
8.	0.040	0.007	100	140	96	44	3.30
9.	045	0.007	100	156	96	60	3.80
10.	0.050	0.008	100	158	96	68	4.20

* Calculated as noted in table A1.1

TABLE A1:3: CALIBRATION DATA FOR SUBJECT C

S No.	Weight (kN)	Scale Reading (kN)	Average Crank Speed (RPM)	HEARTRATE, H (beats min⁻¹) Final	Initial	ΔH	Energy* Expended (kcal)
1.	0.005	0.005	100	96	80	16	0.00
2.	0.010	0.005	100	100	84	16	0.50
3.	0.015	0.005	100	100	80	20	1.00
4.	0.020	0.005	100	112	84	28	1.50
5.	0.025	0.005	100	120	88	32	2.00
6.	0.030	0.007	100	120	80	40	2.30
7.	0.035	0.007	100	136	88	48	2.80
8.	0.040	0.007	100	132	80	52	3.30
9.	0.045	0.007	100	148	80	68	3.80
10.	0.050	0.008	100	162	88	74	4.20

* Calculated as noted in table A1.1.

APPENDIX 2

BASIC INFORMATION ON GROUNDNUT VARIETY USED AND ON ENVIRONMENTAL CONDITIONS

A2.1: Information on Groundnut Variety Used

(i) Groundnut variety used is Manipinta. It is unlisted in the IAR developed varieties indicated by Table 2.2.

(ii) Percentage Oil content of the groundnut was determined to be 43.25%. Analysis was conducted in the laboratories of the Food Science and Technology Research Programme, IAR, ABU.

(iii) Moisture content of the groundnuts used in the experiment was determined to range from 4.8% to 8.2% (wet basis).

(iv) Sieve analysis of the groundnut-paste produced by the IAR Disc Mill indicated average particule sizes within the range 0.43 mm to 0.52 mm.

A2.2: Environmental Factors Measured During Experimental Operations

(i) Temperature Range (°C)

28.5 to 35.5 - dry bulb
22.5 to 35.5 - wet bulb

(ii) Relative Humidity Range (%)

58 to 93.

APPENDIX 3

EXPERIMENTAL DESIGN FOR EVALUATION OF THE KNEADING TOOLS

Table A3.1: 3^3 Factors (fixed effects) Experimental Layout for the Evaluation of Kneading Tools Performances

	$T_{TRADITIONAL}$			T_{IAR}			$T_{DEVELOPED}$		
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
R_R									
R_B									
R_C									

Table A3.2: Analysis of Variance (ANOVA) Table for the 3 Factors (fixed effects) with one Observation Per Cel. (Scheffe, 1959)

Source of Variation		Degree of Freedom
T	Main Effect	t - 1
Q	Main Effect	q - 1
R	Main Effect	r - 1
TQ	Interactions	(t - 1) (q - 1)
TR	Interactions	(t - 1) (r - 1)
QR	Interactions	(q - 1) (r - 1)
TQR	Interactions	(t - 1) (q - 1) (r - 1)
Error		tqr (m - 1)

APPENDIX 3

EXPERIMENTAL DESIGN FOR EVALUATION OF THE KNEADING TOOLS

Table A3.1: 3^3 Factors (fixed effects) Experimental Layout for the Evaluation of Kneading Tools Performances

	$T_{TRADITIONAL}$			T_{IAR}			$T_{DEVELOPED}$		
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
R_R									
R_B									
R_C									

Table A3.2: Analysis of Variance (ANOVA) Table for the 3^3 Factors (fixed effects) with one Observation Per Cell (Scheffé, 1959)

Source of Variation		Degree of Freedom
T	Main Effect	t - 1
Q	Main Effect	q - 1
R	Main Effect	r - 1
TQ	Interactions	(t - 1) (q - 1)
TR	Interactions	(t - 1) (r - 1)
QR	Interactions	(q - 1) (r - 1)
TQR	Interactions	(t - 1) (q - 1) (r - 1)
Error		tqr (m - 1)

NOTES:

(i) In the fixed mode, all the mean Squares (MS) are tested against the error mean square (MSe).

(ii) For one observation per cell, it is necessary to assume that certain interactions are zero.

(iii) If the number of observation per cell is one (i.e. M = 1), it is necessary to assume that certain interactions are zero.

(iv) If the TQR ineractions are assumed to be zero, then the sum square (SS) of the TQR interactions (i.e. SS_{TQR}) of table A3.2 becomes the error Sum Square (i.e. SSe).

(v) If it is also assumed that QR interactions are zero, then:

$$SSe = SS_{QR} + SS_{TQR}; \text{ etc.}$$

APPENDIX 4

MEASURED AND DETERMINED EXPERIMENTAL DATA ON [redacted] TOOLS EVALUATION

TABLE A4:1: Data for Subjects Heartrates, Operational Time and Energy Expenditure for Traditional Pestle

Subject	Quantity Processed @ 1tier = 2.2 kg (Tiers)	HEARTRATE, H (beats/min)			TIME (minutes)			Energy* Expended (kcal)
		Inital	Final	ΔH	Work	Rest	Total	
A.	1	80	104	24	23	5	28	1.75
B	1	88	104	16	24	5	29	1.10
C.	1	76	88	12	31	3	34	0.30
A	2	68	104	36	30	7	37	2.50
B	2	92	116	24	17	3	20	1.65
C	2	80	96	16	19	6	25	0.60
A	3	76	120	44	22	3	25	3.05
B	3	92	124	32	24	2	26	2.20
C	3	80	104	24	26	3	29	1.10

* Obtained from Subjects Calibration Graphs.

TABLE A4:2: Data for Subjects Heartrates, Operational Time and Energy Expenditure for IAR Modified Pestle

Subject	Quantity Processed @ 1tier = 2.2 kg (Tiers)	HEARTRATE, H (beats/min)			TIME (minutes)			Energy* Expended (kcal)
		Inital	Final	ΔH	Work	Rest	Total	
A	1	84	100	16	23	11	34	1.20
B	1	88	104	16	31	10	41	1.10
C	1	76	88	12	21	1	22	0.60
A	2	76	108	32	42	8	50	2.25
B	2	80	112	32	31	7	38	2.20
C	2	72	92	20	24	4	28	0.85
A	3	76	112	36	34	15	49	2.50
B	3	68	112	44	41	8	49	3.00
C	3	76	96	20	45	10	55	0.85

* Obtained from Subjects Calibration Graphs.

TABLE A4:3: Data for Subjects Heartrates, Operational Time and Energy Expenditure for the Developed Kneading Mechanism

Subject	Quantity Processed @ 1tier = 2.2 kg (Tiers)	HEARTRATE, H (beats/min) Inital	Final	ΔH	TIME (minutes) Work	Rest	Total	Energy* Expended (kcal)
A.	1	76	84	8	20	5	25	0.70
B	1	76	100	24	30	10	40	1.65
C.	1	80	84	4	30	5	35	0.00
A	2	72	104	32	29	9	38	2.25
B	2	100	136	36	29	5	34	2.45
C	2	76	108	32	47	7	54	0.65
A	3	68	96	28	20	5	25	2.00
B	3	80	100	20	22	13	35	1.40
C	3	80	96	16	39	8	47	1.60

* Obtained from Subjects Calibration Graphs.

TABLE A4:4: Measured Quantities for Processed Groundnuts, Using Traditional Pestle

Subject	Quantity Processed (Kgs)	MEASURED WEIGHTS (kg) Raw G'nut	Roasted G'nut	Groundnut Paste	Water Added	G'nut Cake	OIL EXTRACTED Primary	Final	Cake	Percent* Fried Oil Extracted	Extraction Efficiency (e_{ff})**
							[redacted] (Kg)/(Kg) (dry basis)				
A	1	2.10	1.80	1.75	0.60	1.70	0.60	0.60	1.20	34.28	0.8
B	1	2.00	1.90	1.85	0.50	1.80	0.50	0.50	1.40	27.03	0.6
C	1	2.20	2.00	1.95	0.70	2.00	0.50	0.50	1.60	25.64	0.6
A	2	4.10	3.50	3.40	1.20	3.60	1.00	1.00	2.40	29.41	0.7
B	2	4.40	4.10	4.00	1.10	4.00	1.00	1.10	2.70	27.50	0.6
C	2	4.20	3.50	3.40	1.00	3.60	1.10	1.10	2.70	32.35	0.7
A	3	6.00	5.30	5.15	1.30	4.90	1.50	1.50	4.50	29.13	0.7
B	3	6.40	5.80	5.65	1.50	5.40	1.40	1.40	4.00	24.78	0.6
C	3	6.20	5.60	5.45	1.50	5.60	1.20	1.20	4.00	22.02	0.5

* Percent Oil Extracted = $\frac{\text{Weight of Oil Extracted}}{\text{Weight of Paste kneaded}} \times 100\ \%$

** $e_{ff} = \frac{\text{Percent Oil Extracted}}{\text{Percent Oil Content of Groundnut Variety Used}} = \frac{\text{Percent Oil Extracted}}{43.25\%}$

TABLE A4:5: Measured Quantities for Processed Groundnuts, Using IAR Modified Pestle

Subject	Quantity	MEASURED WEIGHTS (kg)								Percent* Fried Oil Extracted	Extraction Efficiency
	Processed (tiers)	Raw G/nut	Roasted G/nut	Groundnut Paste	Water Added	G/nut Cake	OIL EXTRACTED Primary	Final	Cake		(e_o)**
							[redacted] (kuli kuli) (dry basis)				
A	1	2.00	1.80	1.75	0.70	2.20	0.10	0.10	1.60	5.71	0.1
B	1	2.20	2.00	1.95	0.60	1.90	0.60	0.60	1.40	30.77	0.7
C	1	2.20	1.40	1.35	0.60	2.20	0.40	0.40	1.50	29.63	0.7
A	2	4.40	3.80	3.70	1.10	3.80	0.80	0.80	2.40	21.62	0.5
B	2	4.00	3.50	3.20	1.00	3.10	1.00	1.00	2.30	31.25	0.7
C	2	4.00	3.70	3.50	1.00	3.50	0.70	0.90	2.70	25.71	0.6
A	3	6.20	5.70	5.35	1.70	5.40	1.50	1.70	3.90	31.77	0.7
B	3	6.00	5.20	4.65	1.50	5.00	1.10	1.10	3.30	23.65	0.5
C	3	6.00	5.50	5.35	1.50	5.50	1.00	1.00	3.90	18.69	0.4

* and **: Obtained as indicated under table A4.4

TABLE A4:6: Measured Quantities for Processed Groundnuts, Using the Developed Kneading Mechanism

Subject	Quantity Processed (tiers)	MEASURED WEIGHTS (kg) Raw G/nut	Roasted G/nut	Groundnut Paste	Water Added	Groundnut Cake	OIL EXTRACTED Primary	Final	Cake	Percent Fried Extracted	Oil Extraction Efficiency (e,)**
							[redacted] (kuli:kuli)			(dry basis)	
A	1	2.00	1.80	1.65	0.50	1.80	0.40	0.40	1.20	24.24	0.6
B	1	2.20	1.90	1.85	0.50	2.00	0.60	0.60	1.30	32.43	0.7
C	1	2.00	1.70	1.55	0.60	1.70	0.40	0.40	1.20	25.81	0.6
A	2	3.80	3.40	3.10	1.00	3.30	0.70	0.70	2.30	22.58	0.5
B	2	4.20	3.80	3.40	1.10	3.60	1.20	1.30	2.50	38.23	0.9
C	2	4.40	3.60	3.40	1.20	4.20	0.80	0.70	2.80	20.59	0.5
A	3	6.20	5.50	5.35	1.80	5.60	1.50	1.60	3.80	29.91	0.7
B	3	5.90	5.10	.5	1.40	4.80	1.50	1.50	3.50	30.93	0.7
C	3	6.40	5.80	5.55	1.40	5.70	1.40	1.50	4.10	27.03	0.6

* and **: Obtained as indicated under table A4.4.

Table A4:7: Samples Data for Overall Height (Stature) for Women

Overall Heights (Stature) (cm)				
168	172	158	161	153
149	161	153	157	161
161	175	168	159	148
161	155	155	156	158
156	162	171	168	154
157	160	163	155	159
153	152	154	159	160
163	175	169	151	164
162	159	168	143	165
172	156	163	164	163

Mean (M) = 160.18 cm
Standard Deviation $(SD)_{n-1}$ = 6.96 cm

(i) Using equation (15),
5th percentile stature = : - 1.65 (SD
= 160.18 - 1.65 (6.96)
= 148.79 cm

(ii) 50th percentile stature = M
= 160.18 cm

(iii) Using equation (14),
95th percentile stature = M + 1.65 (SD)
= 160.18 - 1.65 (6.96)
= 171.66 cm

Table A4:8: Samples Data for Forearm Length for Women

Forearm Lengths (cm)				
24	25	28	25	31
27	24	29	28	29
28	27	27	28	29
28	25	28	27	26
28	25	26	30	26
27	24	27	29	31
29	26	25	29	28
28	24	24	27	29
26	26	25	28	29
28	25	26	27	273

Mean (M) = 27.04 cm
Standard Deviation $(SD)_{n1}$ = 1.83 cm

(i) Using equation (15),
5th percentile Forearm Length = 27.04 - 1.65 (1.83) cm
= 24.02 cm

(ii) 50th percentile Forearm Length= 27.04 cm

(iii) Using equation (14),
95th percentile Forearm Length= 27.04 + 1.65 (1.83)
= 30.06 cm

Table A4:9: Samples Data for Standing-Elbow Height for Women

Overall Elbow Heights (cm)				
94	102	101	104	100
109	95	100	105	111
100	91	104	106	97
100	101	103	109	97
98	96	100	104	96
95	105	99	104	93
98	93	106	94	101
99	98	92	93	91
95	97	101	97	105
97	100	99	93	07

Mean (M) = 99.30 cm
Standard Deviation $(SD)_{n-1}$ = 4.86

(i) Using equation (15),
5th percentile standing Elbow Height = 99.30 - 1.65 (4.86) cm
= 91.28 cm (6.96)
= 148.79 cm

(ii) 50th percentile stature = 99.30 cm

(iii) Using equation (14),
9th percentile standing Elbow Height,
= 99.30 + 1.65 (4.86) cm
= 107.32 cm

Table A4:10: Measured Quantities for Groundnut Deskinning Tools Comparison

Trial No.	Total Operational Time for tier (minut s)					
	Rubbing		Winnowing		Total	
	Existing	Improved	Existing	Improved	Existing	Improved
1	3.1	**1.9**	1.8	**0.5**	4.9	2.4
2	2.9	**2.0**	2.3	**0.5**	5.2	2.5
3	3.0	**1.9**	2.0	**0.6**	5.0	2.5
4	2.9	**1.9**	2.1	**0.5**	5.0	2.4
5	2.9	**2.0**	2.2	**0.5**	5.1	2.5
6	3.2	**2.1**	1.7	**0.4**	5.9	2.5
7	3.1	**2.2**	1.9	**0.3**	5.0	2.5
8	2.9	**2.1**	2.1	**0.5**	5.0	2.6
9	3.0	**2.0**	2.0	**0.6**	5.0	2.6
10	3.0	**1.9**	1.9	**0.6**	4.9	2.5
Sum	30	**20**	20	**5**	50	25
Mean	3.0	**2.0**	2.0	**0.5**	5.0	2.5

Table A4:11: Measured Quantities for "Cake Rolling and Curring" Tools Comparison.

Trial No.	Tool operational Time per Tier (min)	
	Hand	Cake-Roller Press
1	27	11
2	25	12
3	27	10
4	26	9
5	25	10
6	26	10
7	25	9
8	27	9
9	27	10
10	25	10
Sum	260	100
Mean	26	10

APPENDIX 5

STATISTICAL COMPUTATIONS OF EXPERIMENTAL DATA

TABLE A5:1: CALIBRATION DATA ANALYSIS FOR SUBJECT A:

	ΔH (X)	E (Y)	$X - \bar{X}$	SSx $(X - \bar{X})^2$	$Y - \bar{Y}$	SS_y $(Y - \bar{Y})^2$	S_{xy} $(X - \bar{X})(Y - \bar{Y})$
	8	0.0	-23.2	538.24	-2.14	4.58	49.65
	8	0.5	-23.2	538.24	-1.64	2.69	38.05
	16	1.0	-15.2	231.04	-1.14	1.30	17.33
	20	1.5	-11.2	125.44	-0.64	0.41	7.17
	24	2.0	- 7.2	51.84	-0.14	0.02	1.01
	28	2.3	- 3.2	10.24	0.16	0.03	- 0.51
	32	2.8	0.8	0.64	0.66	0.44	0.53
	44	3.[illegible]	12.8	163.84	1.16	1.35	14.85
	60	3.8	28.8	829.44	1.66	2.76	47.81
	72	4.2	40.8	1664.64	2.06	4.24	84.05
Σ	*312*	*21.4*		*4153.6*		*17.82*	*259.94*
Mean	31.2	2.14					

From table,
Regression coeficient, $b_{yx} = \frac{S_{xy}}{SSx}$

$$= \frac{259.94}{4153.60} = 0.063$$

$$\therefore \quad b_{yx} = 0.063$$

Regression Constant,

$$\alpha = \bar{Y} - b_{yx} \cdot \bar{X}$$

$$= 2.14 - (0.063 \times 31.2)$$

$$= 2.14 - 1.79$$

$$\therefore \quad = 0.17$$

$$\alpha = 0.17$$

Hence , Regression Equation for subject A is given as:

$$E = 0.063\ \Delta H + 0.17$$

For correlation between E and ΔH,

Correlation Coefficient, $r_{xy} = \frac{Sxy}{\sqrt{SSx.SSy}}$

$$= \quad = \frac{259.94}{\sqrt{4153.6 \times 17.82}} \quad = \quad \frac{259.94}{\sqrt{74107.152}}$$

$$= \ 0.955$$

$$\therefore \quad r_{xy} \ = 0.955$$

From t - test, $t_{calculated} = 9.107$

From tables, $t_{0.05}$, $\theta_{DF} \ = \ 2.306$

TABLE A5:2: CALIBRATION DATA ANALYSIS FOR SUBJECT B:

	ΔH (X)	E (Y)	$X - \bar{X}$	SS_X $(X - \bar{X})^2$	$Y - \bar{Y}$	SS_Y $(Y - \bar{Y})^2$	S_{xy} $(X - \bar{X})(Y - \bar{Y})$
	8	*0.0*	*-23.2*	*538.24*	*-2.14*	*4.58*	*49.65*
	8	0.5	-23.2	538.24	-1.64	2.69	38.05
	16	1.0	-15.2	231.04	-1.14	1.30	17.33
	20	1.5	-11.2	125.44	-0.64	0.41	7.17
	24	2.0	- 7.2	51.84	-0.14	0.02	1.01
	28	*2.3*	*- 3.2*	*10.24*	*0.16*	*0.03*	*-0.51*
	36	2.8	4.8	23.04	0.66	0.44	3.71
	44	3.3	12.8	163.84	1.16	1.35	14.85
	60	3.8	28.8	829.44	1.66	2.76	47.81
	68	4.2	36.8	1354.24	2.06	4.24	75.81
Σ	[illegible]	21.4		*3865.60*		*17.82*	*254.25*
Mean	31.2	2.14					

From table above,

Regression coeficient, $b_{yx} = \frac{S_{xy}}{SSx} = \frac{254.25}{3865.60}$

$= 0.066$

$\therefore \quad b_{yx} = 0.066$

Regression Constant,

$\alpha = \bar{Y} - b_{yx} \cdot \bar{X}$

$= 2.14 - (0.066 \times 31.2)$

$= 2.14 - 2.05$

$\therefore \quad \alpha = 0.09$

Hence , Regression Equation for subject B is given as:

$E = 0.066\ \Delta H + 0.09$

For correlation between $\hat{E}$ and ΔH,

Correlation Coefficient, $r_{xy} = \frac{Sxy}{\sqrt{SSx.SSy}} = 0.969$

$r_{xy} = 0.969$

From t - t[illegible], $t_{calculated} = 11.093$

From tables, $t_{0.05,\ 8DF} = 2.306$

TABLE A5:3: CALIBRATION DATA ANALYSIS FOR SUBJECT C:

	ΔH (X)	E (Y)	$X - \bar{X}$	SSx $(X - \bar{X})^2$	$Y - \bar{Y}$	SSy $(Y - \bar{Y})^2$	Sxy $(X - \bar{X})(Y - \bar{Y})$
	16	0.0	-23.4	547.56	-2.14	4.58	50.08
	16	0.5	-23.4	547.56	-1.64	2.69	38.38
	20	1.0	-19.4	376.36	-1.14	1.30	22.12
	28	1.5	-11.4	129.96	-0.64	0.41	7.30
	32	2.0	- 7.4	54.76	-0.14	0.02	1.04
	40	2.3	- 0.6	0.36	0.16	0.03	- 0.10
	48	2.8	8.6	73.96	0.66	0.44	5.68
	52	3.3	12.6	158.76	1.16	1.35	14.62
	68	3.8	28.6	817.96	1.66	2.76	47.48
	74	4.2	34.6	1197.16	2.06	4.24	71.28
Σ	394	21.4		3904.40		17.82	258.08
Mean	39.4	2.14					

From table above,

Regression coeficient, $b_{yx} = \frac{S_{xy}}{SSx} = \frac{258.08}{3904.40}$

$= 0.066$

$\therefore \quad b_{yx} = 0.066$

Regression Constant,

$\alpha = \bar{Y} - b_{yx} \cdot \bar{X}$

$= 2.14 - (0.066 \times 39.4)$

$= 2.14 - 2.60$

$\therefore \quad \alpha = -0.46$

Hence , Regression Equation for subject C is given as:

$E = 0.066\ \Delta H - 0.46$

For correlation between E and ΔH,

Correlation Coefficient, $r_{xy} = \frac{Sxy}{\sqrt{SSx.SSy}}$

$= \frac{258}{\sqrt{3904.4 x 17.82}}$

$= 0.978$

$\therefore \quad r_{xy} = 0.978$

From t - test,

$$t = \frac{r_{xy}}{\sqrt{1 - r_{xy}^2}} \cdot \sqrt{n - 2}$$

where n = number of observations (data).

Thus,

$$t_{calculated} = 13.260$$

From tables, $t_{0.05,\ 8_{DF}} = 2.306$

A5.4: Analysis of Varianace with Heartrate Changes as the Index

	T_{TRAD}			T_{IAR}			T_{DEV}			Σ
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	
R_A	24	36	44	16	32	36	8	32	28	256
R_B	16	24	32	16	32	44	24	36	20	244
R_C	12	16	24	12	20	20	4	32	16	156
Σ	52	76	100	44	84	100	36	100	64	656

$$CF = \frac{(657)^2}{27} = \frac{430336}{27}$$

$$\therefore \quad CF = 15938.37$$

$$\text{Total } SS = (24^2 + 36^2 + 44^2 + - - - + 32^2 + 16^2) - CF$$

$$= 18816 - 15938.37$$

$$= 2877.63$$

TR INTERACTION TABLE.

	T_{TRAD}	T_{IAR}	T_{DEV}	Σ
R_A	104	84	68	256
R_B	72	92	80	244
R_C	52	52	52	156
Σ	228	228	200	656

$$TSS = (228^2 + 228^2 + 200^2)/9 - CF$$

$$= \frac{143968}{9} - 15938.37$$

$$= 15996.44 - 15938.37$$

$$\therefore \quad TSS = 58.07$$

$$RSS = (256^2 + 244^2 + 156^2)/9 - CF$$

$$= \frac{149408}{9} - 15938.37$$

$$= 16600.89 - 15938.37$$

$\therefore$ RSS = 662.52

$$\text{TXR SS} = \frac{(104^2 + 84^2 + \ldots + 52^2 + 52^2)}{3} - (\text{CF} + \text{TSS} + \text{RSS})$$

$$= \frac{50656}{3} - (15938.37 + 58.07 + 662.52)$$

$$= 16885.33 - 16658.96$$

$\therefore$ TR SS = 226.37

TQ INTERACTION TABLE

	T_{TRAD}	T_{IAR}	$T_{\cdot\cdot\cdot}$	Σ
Q_1	52	44	36	132
Q_2	76	84	100	260
Q_3	100	100	64	264
Σ	228	228	200	656

$$\text{QSS} = (132^2 + 260^2 + 264^2)/9 - \text{CF}$$

$$= \frac{154720}{9} - 15938.37$$

$$= 17191.11 - 15938.37$$

QSS = 1252.74

Assumption: There is no QR and TQR interactions. Hence, Error (SS) = TQRSS + QR SS.

Thus,

Error SS = TOTAL SS - (TSS + RSS + TRSS + QSS + TQSS))

but,

$$\text{TQSS} = \frac{(52^2 + 44^2 + \ldots 100^2 + 64^2)}{3} - (\text{CF} + \text{TSS} + \text{QSS})$$

$$= \frac{52864}{3} - (15938.37 + 58.07 + 1252.74)$$

$$= 17621.33 - 17249.18$$

$\therefore$ TQSS = 372.15

$\therefore$ Error (SS) = 2877.63 -

(58.07 + 662.52 + 226.37 + 1252.74 + 372.15)

= 2877.63 - 2571.85

∴ Error (SS) = 305.78

TABLE: A5.4 ANOVA TABLE FOR HEARTRATE CHANGES

Source	DF	SS	MS	F
T	2	58.07	29.05	1.139
Q	2	1252.74	626.370	24.581**
R	2	662.52	331.260	13.000**
TXQ	4	372.15	93.038	3.651
TXR	4	226.37	56.593	2.221
Error	12	305.78	25.482	
Total	26	2877.63		

A5.5: Analysis of Varianace with Energy Expenditure as the Index

	T_{TRAD}			T_{IAR}			T_{DEV}			$\sum$
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	
R_A	1.75	2.50	3.05	1.20	2.25	2.50	0.70	2.25	2.00	18.20
R_B	1.10	1.65	2.20	1.10	2.20	3.00	1.65	2.45	1.40	16.75
R_C	0.30	0.60	1.10	0.60	0.85	0.85	0.00	0.65	0.60	5.55
	3.15	4.75	6.35	2.90	5.30	6.35	2.35	5.35	4.00	40.50

$$CF = \frac{(40.50)^2}{27} = \frac{1640.25}{27}$$

$$\therefore \quad CF = 60.75$$

$$\text{Total SS} = (1.75^2 + 2.5^2 + 3.05^2 + - - - + 0.65^2 + 0.60^2) - CF$$

$$= 79.675 - 60.75$$

$$= 18.93$$

TR INTERACTION TABLE.

	T_{TRAD}	T_{IAR}	T_{DEV}	$\sum$
R_A	7.30	5.95	4.95	18.20
R_B	4.95	6.30	5.50	16.75
R_C	2.00	2.30	1.25	5.55
$\sum$	14.25	14.55	11.70	40.55

$$TSS = (14.25^2 + 14.55^2 + 11.70^2)/9 - CF$$
$$= 551.655/9 - 60.75$$
$$= 61.30 - 60.75$$

$$\therefore \quad TSS = 0.55$$

$$RSS = (18.20^2 + 16.75^2 + 5.55^2)/9 - CF$$
$$= \frac{642.605}{9} - 60.75$$
$$= 71.40 - 60.75$$

$$\therefore \quad RSS = 10.6^{r}$$

$$TXR\ SS = (7.30^2 + 5.95^2 + ... + 2.30^2 + 1.25^2)/_3 - (CF + TSS + RSS)$$

$$= \frac{218.49}{3} - (60.75 + 0.55 + 10.65)$$

= 72.83 - 71.95

∴ TR SS = 0.88

TQ INTERACTION TABLE.

	T_{TRAD}	T_{IAR}	T_{DEV}	Σ
Q_1	3.15	2.90	2.35	8.40
Q_2	4.75	5.30	5.35	15.40
Q_3	6.35	6.35	4.00	16.70
Σ	14.25	14.55	11.70	40.50

$$QSS = (8.40^2 + 15.40^2 + 16.70^2)/9 - CF$$
$$= \frac{586.61}{9} - 60.75$$
$$= 65.18 - 60.75$$
$$QSS = 4.43$$

$$TXQ\ SS = \frac{(3.15^2 + 2.90^2 + ... + 6.35^2 + 4.00^2) - (CF+TSS+QSS)}{3}$$
$$= \frac{199.775}{3} - (60.75 + 0.55 + 4.43)$$
$$= 66.59 - 65.73$$

∴ TQ SS = 0.86

Assumption: There is no QR and TQR interactions. Hence, Error (SS) = TQRSS + QR SS = TOTAL SS - (ALL SS)

Thus,

Error SS = TOTAL SS - (ALL SS)

= 18.93 - (0.55 + 10.65 + 0.88 + 4.43 + 0.86)

= 18.93 - 17.37

∴ Error SS = 1.56

TABLE A5.5 ANOVA TABLE FOR ENERGY EXPENDITURE

Source	DF	SS	MS	F
T	2	0.55	0.275	2.115
Q	2	4.43	2.215	17.038**
R	2	10.65	5.325	40.962**
TXQ	4	0.86	0.215	1.654
TXR	4	0.88	0.220	1.692
Error	12	1.56	0.130	
Total	26	18.93		

A5.6: ANALYSIS OF VARIANACE WITH ACTUAL WORKING TIME AS INDEX

	T_{TRAD}			T_{IAR}			T_{DEV}			Σ
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	
R_A	23	30	22	23	42	34	20	29	20	243
R_B	24	17	24	31	31	41	30	29	22	249
R_C	31	19	26	21	24	45	30	47	39	282
Σ	78	66	72	75	97	120	80	105	81	774

$$CF = \frac{(774)^2}{27} = \frac{599076}{27}$$

$$\therefore \quad CF = 22188$$

$$\text{Total SS} = (23^2 + 30^2 + 22^2 + - - - + 47^2 + 39^2) - CF$$

$$= 23942 - 22188$$

$$= 1754$$

TR INTERACTION TABLE.

	T_{TRAD}	T_{IAR}	T_{DEN}	Σ
R_A	75	99	69	243
R_B	65	103	81	249
R_C	76	90	116	282
Σ	216	292	266	774

$$TSS = (216^2 + 292^2 + 266^2)/9 - CF$$
$$= \frac{202676}{9} - 22188$$
$$= 22519.56 - 22188$$
$$\therefore \quad TSS = 331.56$$

$$RSS = (243^2 + 249^2 + 282^2)/9 - CF$$
$$= \frac{200574}{9} - 22188$$
$$= 22286 - 22188$$
$$\therefore \quad RSS = 98$$

$$TXR\ SS = \frac{(75^2 + 99^2 + ... + 90^2 + 116^2) - (CF + TSS + RSS)}{3}$$
$$= \frac{68914}{3} - (22188 + 331.56 + 98)$$
$$= 22971.33 - 22617.56$$
$$\therefore \quad TR\ SS = 353.77$$

TQ INTERACTION TABLE.

	T_{TRAC}	T_{TAR}	T_{DIS}	Σ
Q_1	78	75	80	233
Q_2	66	97	105	268
Q_3	72	120	81	273
Σ	216	292	266	774

$$QSS = (233^2 + 268^2 + 273^2)/9 - CF$$
$$= \frac{200642}{9} - 22188$$
$$= 22293.56 - 22188$$
$$\therefore \quad QSS = 105.56$$

$$TQSS = \frac{(78^2 + 75^2 + ... 120^2 + 81^2)}{3} - (CF + TSS + QSS)$$
$$= \frac{69044}{3} - (22188 + 331.56 + 105.56)$$
$$= 23014.67 - 22625.12$$
$$\therefore \quad TQSS = 389.55$$

QR INTERACTION TABLE

	R_A	R_B	R_C	Σ
Q_1	66	85	82	233
Q_2	101	77	90	268
Q_3	76	87	110	273
Σ	243	249	282	774

$$QR\ SS = \frac{(66^2+85^2 + ... + 87^2 + 110^2)}{3} - (CF+QSS+RSS)$$
$$= \frac{67980}{3} - (22188 + 105.56 + 98)$$
$$= 22660 - 22391.56$$

∴ QR SS = 268.44

Assumption: There is no TQR interactions. Hence, Error SS = TQR SS = TOTAL SS - (ALL SS)

Thus,
Error SS = TOTAL SS - (ALL SS)
= 1754 - (331.56 + 98 + 353.77 + 105.56 + 389.55 + 268.44)

= 1754 - 1546.88

∴ Error SS = 207.12

TABLE A5.6 ANOVA TABLE FOR ACTUAL WORKING TIME

Source	DF	SS	MS	F
T	2	331.56	165.780	6.403*
Q	2	98.00	49.000	1.893
R	2	105.56	52.780	2.039
TXQ	4	353.77	88.443	3.416
TXR	4	389.55	97.388	3.762
QXR	4	268.44	67.110	2.592
Error	8	207.12	25.890	
Total	26	1754.12		

A5.7: Analysis of Varianace with Tool's Extraction Efficiency As Index

	T_{TRAD}			T_{IAR}			T_{DEV}			$\sum$
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	
R_A	0.8	0.7	0.7	0.1	0.5	0.7	0.6	0.5	0.7	5.3
R_B	0.6	0.6	0.6	0.7	0.7	0.5	0.7	0.9	0.7	6.0
R_C	0.6	0.7	0.5	0.7	0.6	0.4	0.6	0.5	0.6	5.2
$\sum$	2.0	2.0	1.8	1.5	1.8	1.6	1.9	1.9	2.0	16.5

$$CF = \frac{(16.5)^2}{27} = \frac{272.25}{27}$$

$$= 10.08$$

$$\text{Total SS} = (0.8^2 + 0.7^2 + 0.7^2 + - \quad - + 0.5^2 + 0.6^2) - CF$$

$$= 10.65 - 10.08$$

$$= 0.57$$

TR INTERACTION TABLE.

	T_{TRAD}	T_{IAR}	T_{DEV}	$\sum$
R_A	2.2	1.3	1.8	5.3
R_B	1.8	1.9	2.3	6.0
R_C	1.8	1.7	1.7	5.2
$\sum$	5.8	4.9	5.8	16.5

$$TSS = (5.8^2 + 4.9^2 + 5.8^2)/9 - CF$$
$$= 91.29/9 - 10.08$$

$$\therefore \quad TSS = 0.06$$

$$RSS = (5.3^2 + 6.0^2 + 5.2^2)/9 - CF$$
$$= 91.13/9 - 10.08$$
$$= 10.12 - 10.08$$

$$\therefore \quad RSS = 0.04$$

$$\text{TXR SS} = \frac{(2.2^2 + 1.3^2 + \ldots + 1.7^2 + 1.7^2)}{1} - (CF + TSS + RSS)$$

$$= \frac{30.93}{3} - (10.08 + 0.06 + 0.04)$$

$= 10.31 - 10.18$

$\therefore$ TR SS = 0.13

TQ INTERACTION TABLE.

	T_{TRAD}	T_{IAR}	T_{DEV}	Σ
Q_1	2.0	1.5	1.9	5.4
Q_2	2.0	1.8	1.9	5.7
Q_3	1.8	1.6	2.0	5.4
Σ	5.8	4.9	5.8	16.5

$$QSS = (5.4^2 + 5.7^2 + 5.4^2)/9 - CF$$

$$= \frac{90.81}{9} - 10.08$$

$$= 10.09 - 10.08$$

$\therefore$ QSS = 0.01

$$TQSS = (2.0^2 + 1.5^2 + ... 1.6^2 + 2.0^2)/_3 - (CF + TSS - QSS)$$

$$= \frac{30.51}{3} - (10.08 + 0.06 + 0.01)$$

$$= 10.17 - 10.15$$

$\therefore$ TQSS = 0.02

QR INTERACTION TABLE

	R_A	R_B	R_C	Σ
Q_1	1.5	2.0	1.9	5.4
Q_2	1.7	2.2	1.8	5.7
Q_3	2.1	1.8	1.5	5.4
Σ	5.3	6.0	5.2	16.5

QR SS = $(1.5^2 + 2.0^2 + ... + 1.8^2 + 1.5^2)/_3$ - (CF+QSS+RSS

$$= \frac{30.73}{3} - (10.08 + 0.01 + 0.04)$$

$$= 10.24 - 10.13$$

$\therefore$ QR SS = 0.11

Assumption: There is no TQR interactions. Hence, Error SS = TQR SS = TOTAL SS - (ALL SS)

Thus,

Error SS = 0.57 -(0.06 + 0.04 + 0.13 + 0.01 + 0.02 + 0.11)

= 0.57 - 0.37

$\therefore$ Error SS = 0.20

TABLE A5.7 ANOVA TABLE FOR OIL EXTRACTION EFFICIENCY

Source	DF	SS	MS	F
T	2	0.06	0.030	1.20
Q	2	0.01	0.005	0.20
R	2	0.04	0.020	0.80
TXQ	4	0.02	0.005	0.20
TXR	4	0.13	0.033	1.32
QXR	4	0.13	0.028	1.12
Error	8	0.20	0.025	
Total	26	0.57		

A5.8: ANALYSIS OF VARIANACE WITH AMOUNT OF WATER USED IN KNEADING AS INDEX

	T_{TRAD}			T_{IAR}			T_{DEV}			Σ
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	
R_A	0.6	1.2	1.3	0.7	1.1	1.7	0.5	1.0	1.8	9.9
R_B	0.5	1.1	1.5	0.6	1.0	1.5	0.5	1.1	1.4	9.2
R_C	0.7	1.0	1.5	0.6	1.0	1.5	0.6	1.2	1.4	9.5
Σ	1.8	3.3	4.3	1.9	3.1	4.7	1.6	3.3	4.6	28.6

$$CF = \frac{(28.6)^2}{27} = \frac{817.96}{27}$$

$$= 30.29$$

$$\text{Total SS} = (0.6^2 + 1.2^2 + 1.3^2 + - - - + 1.2^2 + 1.4^2) - CF$$

$$= 34.42 - 30.29$$

$$= 4.13$$

TR INTERACTION TABLE

	T_{TRAD}	T_{IAR}	T_{DEV}	Σ
R_A	3.1	3.5	3.3	9.9
R_B	3.1	3.1	3.0	9.2
R_C	3.2	3.1	3.2	9.5
Σ	9.4	9.7	9.5	28.6

$$TSS = (9.4^2 + 9.7^2 + 9.5^2)/9 - CF$$
$$= \frac{272.70}{9} - 30.29$$

$$= 30.30 - 30.29$$

$$\therefore \quad TSS = 0.01$$

$$RSS = (9.9^2 + 9.2^2 + 9.5^2)/9 - CF$$
$$= \frac{272.90}{9} - 30.29$$

$$= 30.32 - 30.29$$

$$\therefore \quad RSS = 0.03$$

$$TR\ SS = (3.1^2 + 3.5^2 + ... + 3.1^2 + 3.2^2) - (CF + TSS + RSS)$$

$$= \frac{91.06}{3} - (30.29 + 0.01 + 0.03)$$

$$= 30.35 - 30.33$$

$\therefore$ TR SS = 0.02

TQ INTERACTION TABLE

	T_{TRAD}	T_{IAR}	T_{DEV}	Σ
Q_1	1.8	1.9	1.6	5.3
Q_2	3.3	3.1	3.3	9.7
Q_3	4.3	4.7	4.6	13.6
Σ	9.4	9.7	9.5	28.6

$$QSS = (5.3^2 + 9.7^2 + 13.6^2)/9 - CF$$

$$= \frac{307.14}{9} - 30.29$$

$$= 34.13 - 30.29$$

$\therefore$ $QSS = 3.84$

$$TQSS = \frac{(1.8^2 + 1.9^2 + \ldots 4.7^2 + 4.6^2)}{3} - (CF + TSS + QSS)$$

$$= \frac{102.54}{3} - (30.29 + 0.01 + 3.84)$$

$$= 34.18 - 34.14$$

$\therefore$ $TQSS = 0.04$

QR INTERACTION TABLE

	R_A	R_B	R_C	Σ
Q_1	1.8	1.6	1.9	5.3
Q_2	3.3	3.2	3.2	9.7
Q_3	4.8	4.4	4.4	13.6
Σ	9.9	9.2	9.5	28.6

$$QR\ SS = \frac{(1.8^2 + 1.6^2 + \ldots + 4.4^2 + 4.4^2)}{3} - (CF + QSS + RSS)$$

$$= \frac{102.54}{3} - (30.29 + 3.84 + 0.03)$$

$$= 34.18 - 34.16$$

$$\therefore \quad QR\ SS = 0.02$$

Assumption: There is no TQR interaction. Hence
Error SS = TQR SS
= TOTAL SS - (ALL SS)

Thus,

Error SS = Total SS - (ALL SS)
= 4.13 - (0.01 + 0.03 + 0.02 + 3.84 + 0.04 + 0.02)

= 4.13 - 3.96

∴ Error SS = 0.17

TABLE A5.8 ANOVA TABLE FOR AMOUNT OF WATER USED

Source	DF	SS	MS	F
T	2	0.01	0.005	0.238
Q	2	3.84	1.920	91.428***
R	2	0.03	0.015	0.714
TXQ	4	0.04	0.010	0.476
TXR	4	0.02	0.005	0.238
QXR	4	0.02	0.005	0.238
Error	8	0.17	0.021	
Total	26	4.13		

CORRELATION AND REGRESSION ANALYSIS FOR GROUNDNUT QUANTITY AND THE AMOUNT OF WATER USED IN THE KNEADING OPERATION

Table A5.9: *USING TRADITIONAL PESTLE*

Groundnut Quantity (Tiers)	Equivalent Weight of G/Nut (X)	Average Weight of Water Used (Y)	$(X-\bar{X})$	$(Y-\bar{Y})$	SSx $(X-\bar{X})^2$	SSy $(Y-\bar{Y})^2$	Sxy $(X-\bar{X})(Y-\bar{Y})$
1	2.10	0.60	-2.07	-0.43	4.2849	0.1849	0.8901
2	4.20	1.10	0.03	0.07	0.0009	0.0049	0.0021
3	6.20	32.50	2.03	0.37	4.1209	0.1369	0.7511
Σ	12.50	3.10			8.4067	0.3267	1.6433
Mean	4.17	1.03					

Correlation Coefficient, $r_{xy} = \Sigma xy / \sqrt{SSx \cdot SSy}$

$$= \frac{1.6433}{\sqrt{(8.4067)\ (0.3267)}} = 0.992.$$

Significance Test (t - test) for calculated r_{xy}

$$t = \frac{r_{xy}}{\sqrt{1 - r^2_{xy}}} \cdot \sqrt{n - 2}$$

where n = number of replication = 9,

so, $$t = \frac{0.992}{\sqrt{1 - (0.992)^2}} \times \sqrt{9 - 2}$$

$$= 7.858 \times \sqrt{7}$$

$\therefore$ t = 20.79

Regression Coefficient, bxy = $\frac{Sxy}{SSx}$ = 1.6433/8.4067 = 0.195

Regression Constant, α = 1.03 - (0.195) (4.17) = 0.2169

$\therefore$ Regression Equation is

$$Y = 0.195\ x + 0.2169$$

Table A5.10: **USING IAR MOFIDIFIED PESTLE**

Groundnut Quantity (Tiers)	Equivalent Weight of of G-nut (X)	Average Weight of Water Used (Y)	$(X-\bar{X})$	$(Y-\bar{Y})$	$(X-\bar{X})^2$	$(Y-\bar{Y})^2$	$(X-\bar{X})(Y-\bar{Y})$
1	2.10	0.60	-2.0	-0.47	4.0	0.2209	0.94
2	4.10	1.00	0.0	-0.07	0.0	0.0049	0.0
3	6.10	1.60	2.0	0.53	4.0	0.2809	1.06
Σ	2.30	3.20			8.0	0.5067	2.00
Mean	4.10	1.07					

Correlation Coefficient, $r_{xy} = S_{xy} / \sqrt{SSx \cdot SS_y}$

$$= \frac{2}{\sqrt{(8)\ (0.5067)}} = 0.993.$$

Significance Test (t - test) for calculated r_{xy}

$$t = \frac{0.993}{\sqrt{1 - (0.993)^2}} \times \sqrt{9 - 2}$$

$$= 31.402$$

Regression Coefficient, $b_{xy} = \frac{Sxy}{SSx} = \frac{2}{8}$

$$= 0.25$$

Regression Constant, $\alpha = 1.07 - (0.25)\ (4.10) = 0.045$

∴ Regression Equation is

$$y = 0.25\ x + 0.045$$

Table A5.11: **USING DEVELOPED KNEADING MECHANISM**

Groundnut Quantity (Tiers)	Equivalent Weight of of G/Nut (X)	Average Weight of Water Used (Y)	$(X-\overline{X})$	$(Y-\overline{Y})$	SSx $(X-\overline{X})^2$	SSy $(Y-\overline{Y})^2$	Sxy $(X-\overline{X})(Y-\overline{Y})$
1	2.10	0.50	-2.03	-0.53	4.1209	0.2809	1.0759
2	4.10	1.10	-0.03	0.07	0.0009	0.0049	-0.0021
3	6.20	1.50	2.07	0.47	4.2849	0.2209	0.9729
Σ	12.40	3.10			8.4067	0.5067	2.0467
Mean	4.13	1.03					

Correlation Coefficient, $r_{xy} = S_{xy} \Big/ \sqrt{SSx \cdot SSy}$

$$= \frac{2.0467}{\sqrt{(8.4067)\ (0.5067)}} = 0.992.$$

Significance Test (t - test) for calculated r_{xy}

$$t = \frac{0.992}{\sqrt{1 - (0.992)^2}} \times \sqrt{9 - 2}$$

$$= 20.79$$

Regression Coefficient, $b_{xy} = \frac{Sxy}{SSx} = \frac{2.0467}{8.4067} = 0.24$

Regression Constant, $\alpha = 1.03 - (0.24)\ (4.13) = 0.039$

$\therefore$ Regression Equation is

$$y = 0.24\ x + 0.039$$

A5:12: Analysis of Variance for Groundnut Deskinning Tools Evaluation with Operational Time As Index

Tool Type		
Existing	Improved	Σ
4.9	2.4	7.3
5.2	2.5	7.7
5.0	2.5	7.5
5.0	2.4	7.4
5.1	2.5	7.6
4.9	2.5	7.4
5.0	2.5	7.5
5.0	2.6	7.6
5.0	2.6	7.6
4.9	2.5	7.4
Σ 50	25	75

$$CF = \frac{(75)^2}{20} = \frac{5625}{20}$$

$$= 281.25$$

$$(\text{Total})\ SS = (4.9^2 + 5.2^2 + \ldots\ldots + 2.6^2\ 2.5^2) - CF$$
$$= 312.62 - 281.25$$
$$= 31.37$$

$$(\text{Tool})\ SS = \frac{(50)^2 + 25 - CF}{10}$$

$$= \frac{3125}{10} - 281.25$$

$$= 312.50 - 281.25$$
$$= 31.25$$

$$(\text{Residual})\ SS = (\text{Total})SS - (\text{Tool})\ SS$$
$$= 31.37 - 31.25$$
$$= 0.12$$

Table A5:12 Analysis of Variance Table for Groundnut Deskinning Tools

Source	DF	SS	MS	F
Tool	1	3.25	31.25	4664.18***
Residual	18	0.12	0.0067	
Total	19			

From tables,
$F_{0.05,\ 18DF} = 4.41$

A5:13: Analysis of Variance for Cake Rolling And Cutting Tools Evaluation with Operational Time As Index

Tool Type			
	Hand(H)	Press(P)	Σ
	27	11	38
	25	12	37
	27	10	37
	26	9	35
	25	10	35
	26	10	36
	25	9	34
	27	9	36
	27	10	37
	25	10	35
Σ	260	100	360

$$CF = \frac{(360)^2}{20} = \frac{129600}{20}$$

$$= 6480$$

$$(\text{Total})\ SS = (27^2 + 25^2 + \ldots\ldots + 10^2 + 10^2) - CF$$
$$= 7776 - 6480$$
$$= 1296$$

$$(\text{Tool})\ SS = \frac{(260)^2 + (100) - CF}{10}$$

$$= \frac{77600}{10} - 6480$$

$$= 7760 - 6480$$
$$= 1280$$

$$(\text{Residual})\ SS = \text{Total SS} - \text{Tool SS}$$
$$= 1296 - 1280$$
$$= 16$$

Table A5:13 Analysis of Variance Table for Cake Rolling and Cutting Tools

Source	DF	SS	MS	F
Tool	1	1280	1280	1439.82***
Residual	18	16	0.889	
Total	19			

From tables,

$F_{0.05,\ 18DF} = 4.41$

COMPARATIVE PRODUCTION COST ANALYSIS BETWEEN EXISTING TOOLS AND THOSE DEVELOPED FROM STUDIES

Production Cost Analysis for Kneading Tools

(a) **Traditional Pestle**

This is cut and shaped directly from appropriate tree branches by desired operators. Basically, it could be assumed costless to the operator. Typical dimension (averagely) is about 2.0 metre length and 0.05 metre diameter.

TABLE A6.1 IAR MODIFIED PESTLE

No.	Component Name	Required Material(s) and Size(s)	Quantity Required	Material Cost (₦)	Finishing Cost (₦)	Overall Cost (₦)
1	Piston	Wood (Mahaogony recommended $(11 \times 11 \times 120)_{cm}$	1	200.00	100.00	300.00
2.	Cylindrical rings	Wood (Mahagony recommended $(11 \times 11 \times 20)_{cm}$	2	70.00	80.00	150.00
3.	Piston Pivot-box	Wood $(20 \times 20 \times 5)_{cm}$	2	40.00	200.00	240.00
4.	Clamps	-Flat iron Bars (1 inch)	Half length	350.00	-	350.00
		-Bolts and Nuts	4	60.00	-	60.00
		-Electrodes	4	18.00	-	18.00
5.	Wooden Screws	8½ inches	2 Dozens	50.00	-	50.00
6.	Metal Pipe	15cm x ϕ 1.5$_{cm}$	1	35.00	-	35.00
				TOTAL FOR MATERIALS/FINISHING		1203.00
				ASSEMBLY COST		70.00
				TOTAL PRODUCTION COST		1273.00

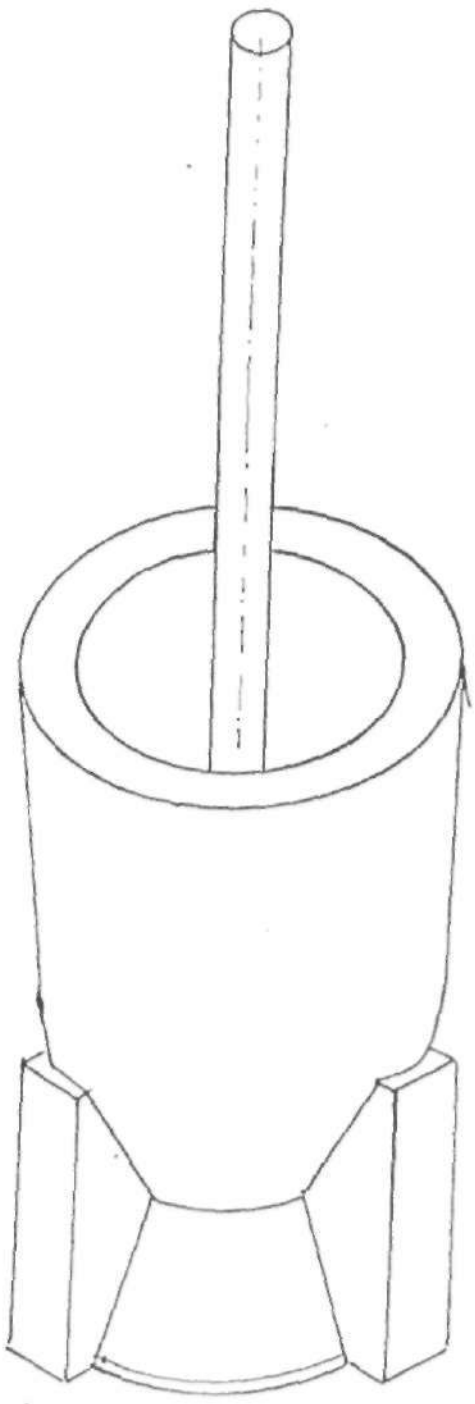
Thus, the average production cost for the IAR Modified Pestle is approximately ₦1300.00 per unit.

TABLE A6.2 DEVELOPED KNEADING MECHANISM

No.	Component Name	Required Material(s) and Size(s)	Quantity Required	Material Cost (₦)	Finishing Cost (₦)	Overall Cost (₦)
1	Shaft	Wood (Mahaogony recommended $(11 \times 11 \times 60)_{cm}$	1	100.00	50.00	150.00
2.	Cylindrical rings	Wood (Mahagony recommended $(11 \times 11 \times 20)_{cm}$	2	70.00	80.00	150.00
3.	Bearing Enclosure	Wood $(20 \times 20 \times 5)_{cm}$	2	40.00	200.00	240.00
4.	Clamps	-Flat Iron Bars (1 inch)	Half length	350.00	-	350.00
		-Bolts and Nuts	4	60.00	-	60.00
		-Electrodes	4	18.00	-	18.00
5.	Wooden Screws	8½ inches	2 Dozens	50.00	-	50.00
6.	Ball Bearing	Single Row (200 series)	1	150.00	-	150.00
7.	Torque Plate	Wood (Mahagony Recommended)	1	35.00	50.00	85.00
8.	Torque Handle	Wood	1	20.00	90.00	110.00
9.	Fingers (Stirrers)	Wood (off cuts)	8	10.00	10.00	20.00
10.	Metal Pipe	15cm x ϕ 1.5cm	1	35.00	-	35.00
					TOTAL FOR MATERIALS/FINISHING	1418.00
					ASSEMBLY COST	100.00
					TOTAL PRODUCTION COST	1518.00

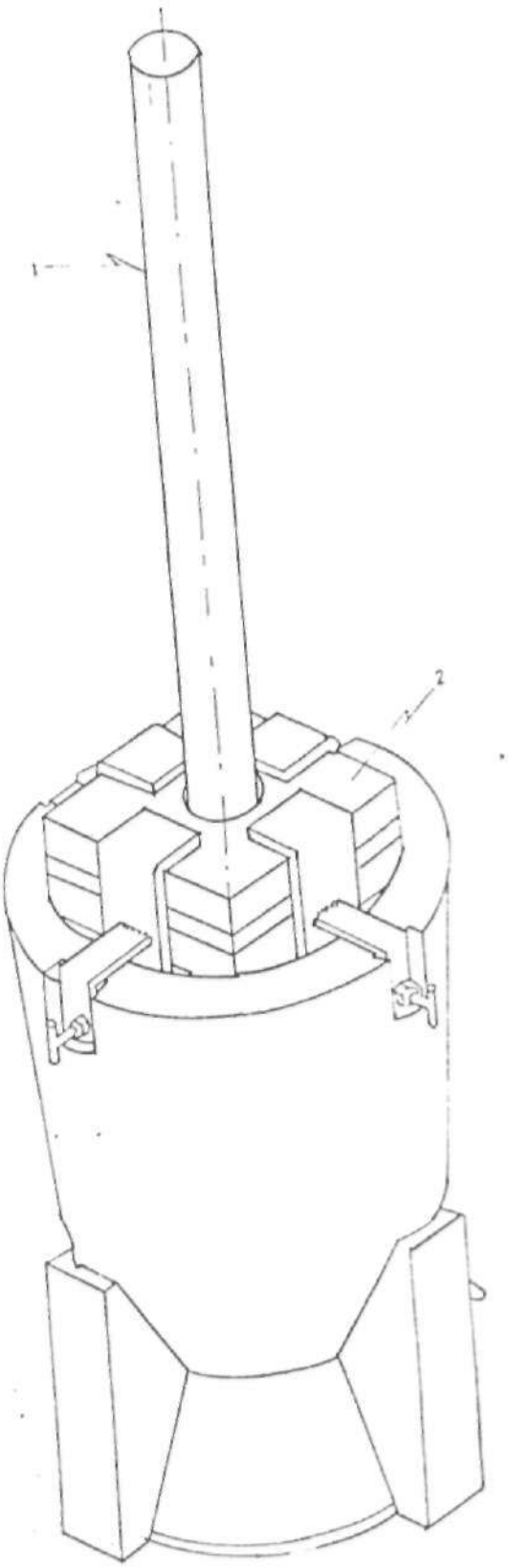
Thus, the average production cost for the Developed Kneading Mechanism is approximately ₦1500.00.

APPENDIX 7



A7 : Isometric view of the traditional pestle and mortar for kneeding

APPENDIX 8



A8 : Isometric view of the I.A.R. modified pestle and mortar for kneeding.