ENGINEERING

TOWARDS MECHANISATION OF FUFU POUNDING

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ABSTRACT

The paper presents an overview of the various approaches to the pounding of Fufu, a common West African meal. In doing so, it describes the indigenous approach to Fufu pounding and highlights the drawbacks of this method, particularly its physical and health hazards, namely, lack of safety to operators and proneness to atmospheric contamination. Past attempts by Ghanaian inventors to produce mechanical devices as alternative to the indigenous approach are also examined. It is pointed out that the mechanical devices have not been fully successful in producing Fufu of the right plasticity and consistency as desired by Ghanaians. These machines have failed because they are incapable of sufficiently pulverising the foodstuff due to their inherent difficulties of sustaining the required power input. For best results, the boiled carbohydrate must be pulverised into a wet powdery form before binding itself into Fufu.

1. INTRODUCTION

1.1 The Meal, Fufu

Fufu is a typical Ghanaian meal that is prepared by pounding some boiled foodstuff or a combination of foodstuffs, namely yam, plantain, cocoyam and cassava. It is eaten together with one of various soups at a time, such as palm or groundnut or light soup. Therefore, a dish of Fufu consists of the pounded foodstuff immersed in a bowl of soup and it is consumed in lumps dipped into the soup.

Taken together with the appropriate soup, Fufu is considered to be very nutritious and palatable. However, most of all the nutritional values are contained in the soup that goes with it. Consequently, the soup is usually prepared very elaborately with a conglomeration of several vegetables, meat (bush and domesticated) and fish or poultry.

It is noteworthy that, in many Ghanaian homes, mostly women and children are relegated to undertake the chores of Fufu preparation. On return from the farm, the village housewife is accustomed to preparing the meal from raw staple foodstuff and ingredients (whole tomatoes, pepper, onions, etc.) with the assistance of the children if they are back from school.

1.2 Foodstuffs

In Ghana Fufu may be prepared from a number of foodstuffs, mainly yam, cocoyam, plantain and cassava. Any of these may be pounded alone to yield the required Fufu, which is then described after the name of the particular foodstuff, such as Yam Fufu, etc. Otherwise, each of the first three foodstuffs may be combined with cassava in varying ratios depending upon the degree of plasticity required to meet one's taste. Such combinations of base foodstuff with cassava appear to be greatly preferred by most Ghanaians to the single-base Fufu in view of the high degree of plasticity that is attainable with the cassava combination. Thus, for most connoisseurs of Ghanaian Fufu, plasticity appears to be a most desirable requirement of the texture of Fufu, unlike the Nigerians and Togolese who prepare Fufu with the single foodstuff, mostly yam, and consequently the resulting Fufu is not as plastic as the Ghanaian Fufu.

2. INDIGENOUS PREPARATION OF FUFU

2.1 Process

The process of Fufu preparation begins by cooking the desired foodstuff(s) in boiling water for a while to a suitable degree of softness in order to remove the rawness in fresh foodstuffs. For cassava, in particular, cooking removes the cyanide contained in it. The cooked foodstuff is generally dried in the open air to some extent and then fed gradually in small amounts into a mortar to be pounded by means of the reciprocating motion of a pestle as depicted in Figs. 1 and 2. These illustrations show the pounder heaving the pestle. In the real situation, the pounder throws up the pestle about half a meter high and then, aiding its downward movement with a minimum of effort, releases it to fall heavily on the foodstuff spread in the mortar. This reciprocating motion is executed repeatedly to provide the pounding action required to smash the foodstuff. Since straight pounding alone does not produce the desirable texture of the mashed stuff, the reciprocating motion of the piston is accompanied by an appropriate mixing and turning process as well as intermittent watering.

In the Ashanti and some coastal areas of Ghana, the mixing and turning process is achieved by hand. On the other hand, in the Volta and Northern


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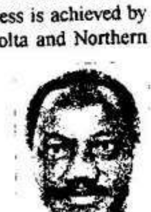
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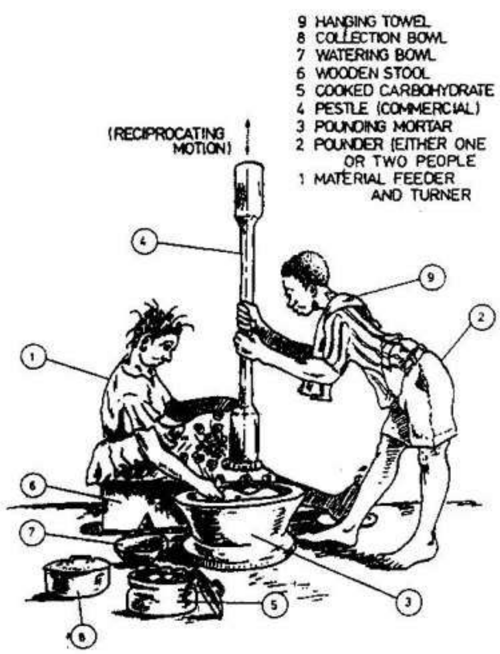

Fig 1. Indigenous Pounding in Broad Shallow Mortar and Commercial Size Pestle

regions, the required turning/mixing action depends on the relative angle between the pestle and mortar as well as the pounding action, which tends to scoop up the material. Thus, in these regions where manual turning of the food stuff is eliminated, a suitable mortar is employed, which can be deftly manipulated by means of the pestle to produce mixing/turning of the foodstuff without any direct human intervention in the turning process. See Fig. 2.

Watering is by hand in both cases. In the case where mixing/turning is done manually, the same hand applies the water at appropriate intervals. In the second situation, which is without hand mixing, water is introduced externally at intervals by hand or by means of a cup of water gradually and sparsely sprinkled into the mortar.

2.2 Maintaining Desirable Characteristics

The desirable characteristics of the texture of Fufu appear to be mainly smoothness, homogeneity and plasticity. The indigenous processes of cooking, drying, gradually feeding, pounding, watering and kneading the material in that sequence are each calculated to produce these characteristics in varying degrees of effectiveness. Hence, for example, cooking and gradual feeding of the foodstuff into the mortar ensure that the foodstuff is properly mashed to minimise losses. Again, turning obviously results in a homogeneous texture. In addition, hard and unmashable food lumps or pebbles are quickly removed during pounding by admirable dexterity of the kneader's hand to make the Fufu smooth and homogeneous on finish.

2.3 Indigenous Pounding Units

The indigenous approach to the production of the right consistency of Fufu is to use a mortar and a pestle to pound the foodstuff, the mortar houses the foodstuff and the pestle smashes it by pounding.

The Mortar

The mortar is a hollow block carved from two types of wood known as "kusia" and "Danta". The cavity is given a smooth finish to make it safe for the bare fingers that are applied to turn the foodstuff in some instances. There are basically two types of mortar, namely, the shallow broad mortar and the deep narrow one (Fig.3 a and b). The shallow broad mortar is generally found in the Ashanti and Brong Ahafo regions, and the deep narrow mortar in the Volta and Northern regions.

It is interesting to note that the structural differences between the two models are dictated by the fact that the Ashanti/Brong Ahafo shallow broad mortar necessitates the turning of the foodstuff by human hand since mere pounding in this type of mortar hardly turns the medium over. Hence, its

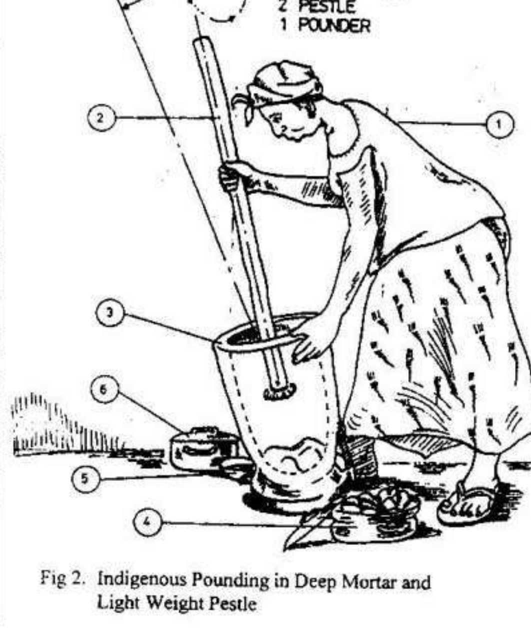

Fig 2. Indigenous Pounding in Deep Mortar and Light Weight Pestle

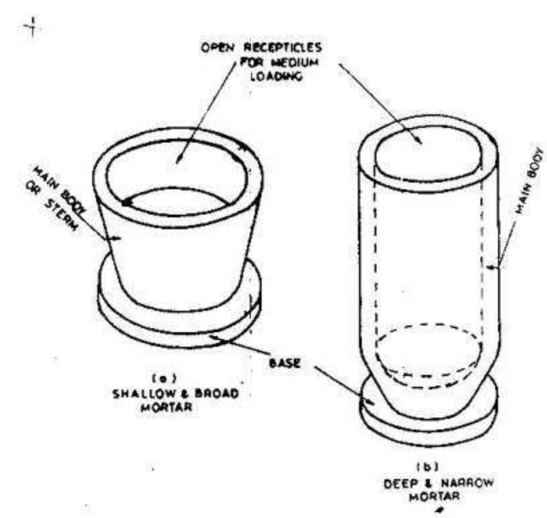

Fig 3. Types of Mortar

broadness is meant to allow room for the hand to manoeuver properly while turning the foodstuff. No human hand is needed to turn the medium in the Northern/Volta version and as such only one person is required for the entire process of pounding. Its narrowness allows enough room for only the medium and pestle. Therefore, the shallow broad mortar requires two people for Fufu processing, one to pound the foodstuff and the other to turn it. However, for domestic applications of a small mortar, one person can perform the two functions of pounding with one hand and turning with the other, as shown in Fig. 4. In any case, the use of either mortar requires a lot of skill as seen in Figs. 1, 2 and 4.

It is also noteworthy that the deep and narrow mortar has its cavity tapering downward and ending with a hemisphere at the bottom. Dropping the pestle to touch any part of the bottom arc causes the mortar to lose balance. This instability or mechanical imbalance is indeed intentional and turns out to be advantageous. Again, owing to the narrowness of the Northern/Volta model, the pestle tends to force the uppermost layer of foodstuff down to the bottom and consequently to bring the lower layer up. Thus, when the deep narrow mortar is in use, its unique imbalance and the displacement of the lower material by the upper combine to bring about the desired turning of the foodstuff. Indeed, the tendency for the pestle to cause mixing by simple impact on the foodstuff and the mortar is very pronounced and highly noticeable at the beginning of the pounding process when chopped pieces of the foodstuff are introduced into the mortar. This turning effect reduces slightly towards the completion of the pounding. However, the dexterity of the pounder as evidenced by his/her judgement in pointing the pestle at the right angle and in the right direction contributes immensely in maintaining proper mixing even towards the end of the pounding process when the stuff is quite sticky. See Fig. 2.

The Ashanti/Brong Ahafo model of shallow and broad mortar does not lend itself to such manoeuvrability of pestle and mortar to cause medium turning on the impact of the pestle and so the human hand of the kneader or turner is required to turn the foodstuff in tandem with the pounder. Unusual dexterity is however required by both the pounder and the kneader in co-ordinating their actions so that the pestle does not smash the fingers of the turner instead of the foodstuff.

It may be observed that pounding in the initial stage is by short, rapid strokes or pulses in both the shallow and deep mortars in order to quickly pulverise the foodstuff while reducing spillage and vibration to some extent. Much longer strokes are later delivered obviously to increase force and, with the deep mortar, to enhance mixing/turning.

The Straight Pestle

The normal pestle is a long, slender wooden stick shaped out of a kind of wood called "woma" by which the stick is called in the Ashanti language. Measuring between 2 and 3m, the pestle has a hairlike brush, formed like mushroom at the working end.

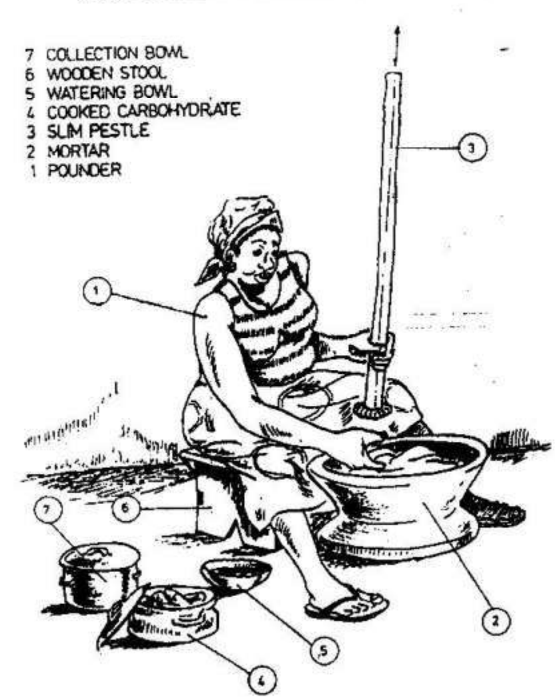

Fig 4. Indienous pounding in shallow mortar and Domestic Pestle showing Pounder Pounding with One Hand and Turning, Watering with the other

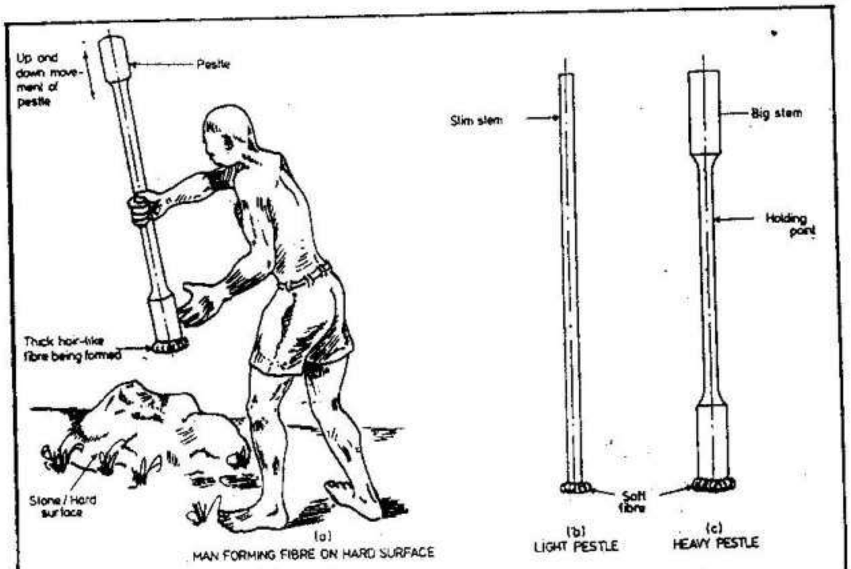

Fig 5. Production of the Pestle

This working end is obtained by pounding the end against a hard rigid surface such as that of a stone until it loosens into radial fibres which curve outward to give it the mushroom shape (vide Fig. 5, b and c).

Fig. 5 (a) shows the mushroom end of the pestle being produced on a hard surface, usually a stone. The fibres of a good pestle are so strong and flexible that they are not easily severed from the pestle until after a long use. The hairlike mushroom end provides a cushioning effect during mashing and consequently minimises the wear on or damage to the mortar in spite of frequent and rapid impact by the pestle and also suppresses spillage or flying of the foodstuff. And so, while the working end of the pestle requires periodic repair by cutting and reforming the "mushroom", a good mortar lasts for a very long time.

The Hammerlike Pestle

Very recently, what appears in the indigenous pounding situation to be a novelty is a hammer-like pestle that has been shown on the Ghana Television for pounding Fufu in a regular mortar.

By this apparent innovation, the much-accustomed rectilinear reciprocating motion of the straight pestle is replaced by a curvilinear or semi-circular motion in a vertical plane produced repeatedly by swinging the Hammerlike pestle. The pounder, while stooping, firmly grips the handle or shaft of the "hammer" with the two hands and swings it to execute the semi-circular motion. At the end of the downward motion, the head of the "hammer" heavily and sharply drops to smash the foodstuff in the mortar. See Fig. 6

This Hammerlike pestle has some obvious disadvantages and advantages over the straight pestle. Some of the disadvantages are as follows:

- The joint of the shaft and head is likely to fail long before the mushroom end of the head is worn out to need repair. And so, it is mechanically weaker than the straight pestle.
- The fibrous mushroom end cannot be repaired by cutting and repairing. In fact, the current and only repair method of hitting the end of the pestle against a hard surface cannot be effectively applied to such a short piece as the head of this pestle.
- Pounding with this pestle may take a longer time due to the relatively longer distance (arc) the pestle is swung through in order to be nearly as effective as the straight pestle; the longer the distance travelled the longer the time taken at the same velocity!.
- The effectiveness of its stroke is greatly suspect. For, the gravitational force provided by its apparently very limited weight compared to that of the straight pestle is much lower. This is also an additional factor affecting Fufu production time. The head of the hammer may generally weigh less than 1/5 of the weight of the straight pestle.
- The required stooping posture of the pounder may easily lead to problems including severe physical strain. The alternative of sitting down to heave the pestle may not be conducive to serious and effective pounding.
- The swinging action can be fatal to the kneader if the pounder swings incorrectly.

The main advantage over the straight pestle seems to stem from the length of the stroke of the

Fig 6. Fufu Pounding with the Hammer-like Pestle

"hammer". A conservative estimate is that the length of the curved stroke of the "hammer" is more than twice the rise or fall of the straight pestle. In spite of its disadvantages mentioned above this long stroke is at the same time advantageous in that it may considerably facilitate co-ordination between the turner and pounder; indeed, the long stroke periods may permit better and more flexible and relaxed regulation of the processes of turning and watering by the turner.

This "hammer" approach to pounding is yet to be popularised. It is presumed that its introduction was originally influenced by some enterprising volunteers of the Japanese Volunteer Group working in a Ghanaian village, judging from the circumstances surrounding its first publicity in the news media. In any case, it is the view of the authors that its disadvantages outweigh the advantages.

3. APPRAISAL OF INDIGENOUS UNITS

3.1 Uniqueness of the Indigenous Units

Many unique functional characteristics of the indigenous units have been mentioned above, including ease of handling, manoeuvrability and adaptability. Besides these, the indigenous units have such commendable features as: simplicity of design, ease of repair and of maintenance, and low cost or affordability as well as availability, durability and suitability of materials.

The simplicity of the indigenous unit is obvious from the fact that it has only two components, a hollow mortar and a straight pestle, with several concomitant advantages. First, the simple mortar, which is the only component whose production calls for special skill, does not require special tools and can be carved out easily by any master craftsman. Secondly, its low cost or affordability by the average Ghanaian home is largely attributable to the unit's simple features with obviously low production time and cost. Lastly and probably most importantly, its ease of repair and of maintenance is also due solely to its simplicity.

There is no gainsaying the fact that the materials for the indigenous unit are readily available, and are also most suitable and durable. As mentioned already, a good mortar lasts for years. And so, the production and operation of the indigenous unit can neither be faulted nor protested by the environmentalists. In any case, any allusions to deforestation or depletion of trees resulting from the production of the indigenous unit may be easily countered by the fact that the two required wood species can be easily nursed and grown abundantly if necessary to mitigate any adverse impact on the environment due to frequent felling of the typical tree.

3.2 Drawbacks of the Indigenous Units

The main drawbacks of the indigenous units are as follows:

- Expenditure of Human Energy
- Tardiness in Processing

- High Risk of Contamination
- Operational Hazards
- Loss of Foodstuff
- High Noises and Vibration

The first four drawbacks are discussed briefly below.

Expenditure of Human Energy

To pound foodstuff by means of the indigenous units to produce Fufu of the right texture requires high expenditure of human energy by the pounder. The second person required to knead or turn the foodstuff, as in the Ashanti/Brong Ahafo model, uses energy to a lesser degree. The authors estimate that the hired Fufu pounder expends approximately 20kW to produce 8kg of Fufu in 32 minutes.

Tardiness in Processing

Pounding of Fufu by means of any of the two pounding units described above takes a very long time. On the average, a normal ball of Fufu required for three or four people may take approximately twenty minutes to pound. Incidentally, a normal size mortar for domestic applications can hold foodstuff just enough to feed three or four people; the industrial pounding unit may contain about twice as much foodstuff per pounding cycle.

High Risk of Contamination

There is high risk of contamination of the foodstuff mainly from three sources. Firstly, the direct exposure to the atmosphere of the foodstuff by virtue of the open mortar may easily subject the foodstuff to direct atmospheric contamination. Though this is seldom noticeable, it is very real and can lead to dire consequences to health in unhygienic surroundings.

Secondly, the pounder usually perspires profusely as a result of high expenditure of energy, and so his/her sweat inadvertently drops into the foodstuff to cause undesirable contamination. To curtail or minimise such contamination, the pounder of the commercial unit in particular periodically wipes off his own sweat with a towel hanging on his shoulder. See Fig. 1 item 9.

Lastly, and probably the most serious source of contamination is by the turner. He or she repeatedly has to dip his/her hand into a bowl of water or scoop a little water from a bowl in order to "grease" his/her hand and to wet the foodstuff by turning it so as to soften the foodstuff and hence to produce the desired consistency and plasticity. In view of this, the Volta/Northern region pounding unit offers better conditions of hygiene since the turner is eliminated completely in this instance.

Operational Hazards

The operation of the indigenous units, notably the Ashanti/Brong Ahafo model, is fraught with considerable hazard. For, it is possible for the turner to have his/her fingers inadvertently smashed due to poor co-ordination between the turner and pounder. It is for this reason that the operators of the pounding unit are enjoined to fully concentrate on their task. It is not uncommon for parents to continually issue warning instructions to their children when the latter take turn in pounding or turning Fufu, particularly if they are the gullible type, for fear of having their own or somebody else's fingers smashed.

In spite of this possibility, operators of large size commercial units, particularly the pounders, are known to make rhythmic sounds that synchronise with the rise and fall of the pestle. A casual observer may think that these spasms of sounds may disturb with or intrude on the pounders' concentration. On the contrary, a little introspection may reveal that such sounds rather aid greatly in the pounders' concentration by blocking away all extraneous sounds, which may otherwise distract them. Indeed, the commercial production of Fufu seldom results in the smashing of fingers owing not only to the superb dexterity and co-ordination capabilities of the pounders and turner but also to their high degree of concentration, in spite of the accompanying sounds. Hence, these sounds are highly complementary and conducive to good performance of the task at hand and tend to ease the tedious labour of pounding.

4. MECHANISATION OF FUFU POUNDING

4.1 Justification for Mechanisation

Many diverse views have been expressed on the desirability or otherwise of mechanising the pounding of Fufu. Among those who still support the retention of the traditional indigenous approach, the overriding view usually expressed is that machine-processed Fufu will never taste the same as that produced with the pounder's sweat and other extraneous ingredients inevitably drawn into it.

On the other hand, it is widely acknowledged that Fufu produced totally by the mechanical equipment may quickly gain acceptance as users or consumers of the product recognise the labour-saving benefits mechanisation brings with it, among others. As in the introduction of any new gadget, in the course of time, people may gradually acquire the taste for the new product of the device as they see its many advantages. In any case, a mechanical device that attempts to remove the tremendous labour and drudgery imposed mostly on women and children by Fufu pounding may obviously be a welcome relief.

Whatever the arguments may be the drawbacks of the indigenous pounding units enumerated in the previous section call for a mechanical device that will successfully circumvent them without introducing any undesirable effects. And so, since 1960 many Ghanaian engineers and technicians have attempted to design and fabricate mechanical contraptions for pounding Fufu.

These attempts are briefly reviewed in the following sections. For easy identification, the various mechanical devices are introduced under the name of the inventor(s) if known and are called as such for purposes of discussion.

4.2 Brief Review of Past Mechanical Units

Serious Ghanaian attempts at the design of a mechanical unit for pounding Fufu probably began with the prototype Fufu machine exhibited at the Ghana International Trade Fair of 1967. Probably spurred on by this exhibition, several designs of Fufu machines have been undertaken and given considerable publicity even without sufficiently proven success. Notable among these contraptions are, chronologically, beginning with the above-mentioned

- Exhibit at Ghana Trade Fair of 1967
- Dr. Quansah's gear unit
- George Kisiedu's screw transporter unit
- K O Anane's two-wooden-pounder arrangement, the KOA
- S K Cherbu's elaborate linkage reciprocator, the CHERBU
- Gyarba's Wormame pounder
- Mechanical reciprocator cum indigenous human kneading unit.

These units are largely based on the principles of reciprocating or rotary motion to achieve a measure of pounding; their detailed descriptions are given in Ref. (1).

4.3 Typical Mechanical Units

As typical examples of past reciprocating and rotary units, Mr S K Cherbu's machine, called the CHERBU after the inventor, and Dr Quansah's gear machine are chosen for a brief description below.

S K CHERBU, ACCRA, 1980

Figure 7 depicts the CHERBU with its characteristically elaborate linkage mechanism.

Its main components are the mortar(1), pestle(2), turning rod(3), watering can(4) and the driving mechanism, consisting of a lever(5) at one end of which is the pestle. At the other end of the lever is a slotted link(6) that connects the lever to the rim of a rotating wheel(7) fixed to the mortar.

It is designed to be coupled by means of a belt to a prime mover or to be operated by a person driving the wheel. The linkage reciprocates vertically together with the lever and pestle. The tension spring attached to the lever is obviously stretched to store energy during the rise of the pestle and to release this energy for pounding when the pestle moves down. Mounted on its own lever(9) that is attached to the main lever, the reciprocating turning rod moves down to knead the foodstuff as the pestle rises. The mortar has a cover on

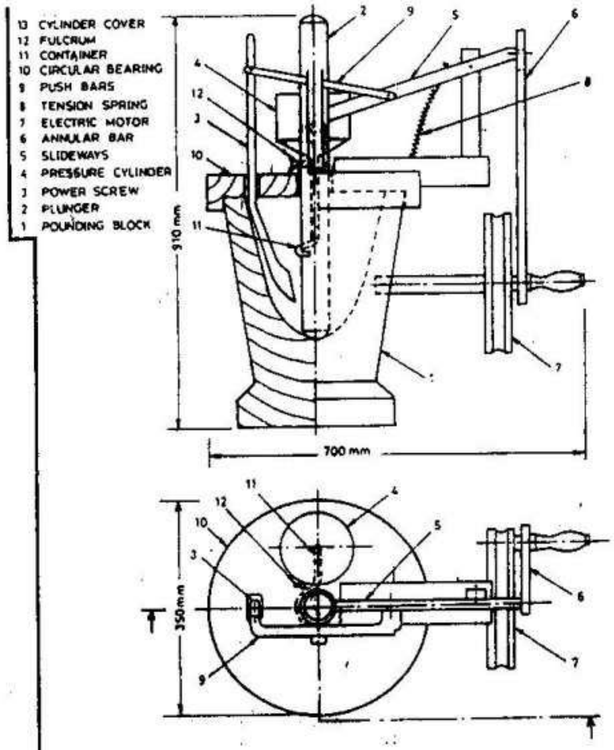

Fig 7. The Cherbu

which the levers are mounted. Water under the control of a valve(12) is delivered from the watering can through the pipe (11) and flows around the pestle. All components are in wood except the watering can, pipe, bolts, nuts and spring, making it safe for food processing.

Like the KOA (Ref.1), this machine is quite simple and easily transportable. Again, it is relatively inexpensive but, unlike the KOA, it provides protection of the medium from contamination. However, besides being grossly ineffective upon testing, it has been found to have the following drawbacks:

a) Improper distribution of water which tends to concentrate in a small area, making turning of the foodstuff difficult and yielding poor texture of Fufu in the final analysis;

b) Difficulty in observing the foodstuff during pounding.

W A Quansah, 1967-1969

For nearly two years of the late 60's Dr W A Quansah, then a Senior Lecturer at the University of Science and Technology, Kumasi, undertook extensive research and development (indeed experimentation!) with the use of gears as a possible alternative for pounding Fufu to the impact methods described above. The carbohydrate when trapped between gear teeth is subjected to extrusion, shearing and impacting actions.

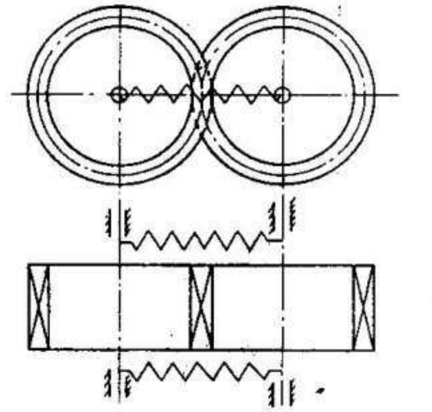

Fig 8. Spring Loaded Wooden Spur Gears.

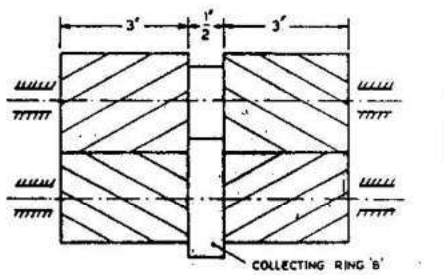

Fig 9. Double Helical Gears (In Brass)

On the basis of this concept, Dr Quansah used a pair of spring - loaded wooden spur gears in some of his preliminary tests as shown in Fig. 8. He found that sufficient energy could be imparted to the carbohydrate cells to cause their rupture. Using two springs each with a stiffness of $400kN/m^2$ in the arrangement shown in Fig. 8 about twelve passes were required to approach the completion of the Fufu making process. It was then obvious that for a commercial design along these lines a step ladder would be an essential capital item.

To circumvent this problem, the design was modified as follows.

A pair of 5cm diameter by 7.5cm length double helical brass gears A shown in Fig. 9 were therefore made and mounted on fixed centres. These were run with "apex trailing" and the Fufu was collected in the central portion by means of ring B. The products made from this simple machine were reported to be successful.

His Research and Development work culminated in the more elaborate unit shown in Fig 10. The machine shown diagrammatically in Fig. 10

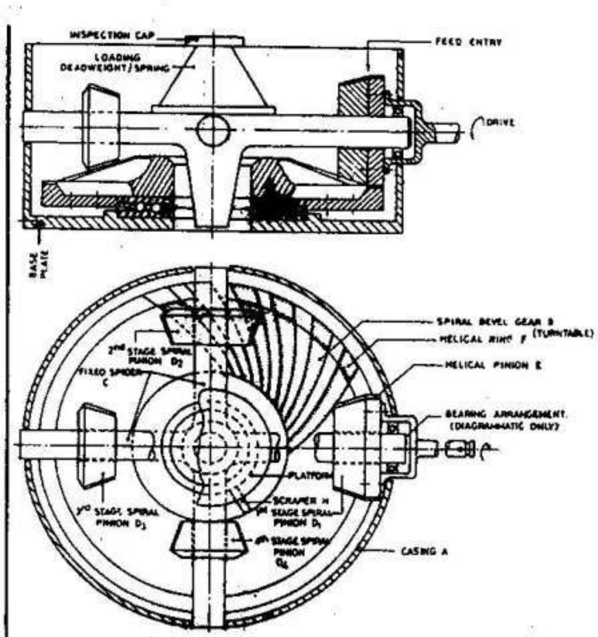

Fig 10. Fufu Procesing Unit

consists of a cylindrical casing A of about 40cm diameter and 20cm height in which is mounted a rotatable anvil B in the form of Spiral bevel gear. Mounted also in the casing is a fixed spider C on whose arms are four rotatable spiral pinions D_1, D_2, D_3 and D_4 that engage the teeth on the anvil. The pinion D_1 is driven by means of an attached gear E which mates with an annular gear ring F on the anvil. There may be several acceptable alternatives for driving the anvil and also for the type of mountings to enable force balance to be achieved.

A hole G exists at the centre of the anvil through which the processed material is discharged with the help of the scraper H mounted on the spider just near the pinion D_1... The aperture may be kept moist to avoid sticking. There is also the provision of a spring or dead weight for increasing the axial load on the spider and hence the meshing pressure if necessary.

Operation of the mill is clear; the material to be treated is fed into the casing at the point where the pinion D_1 meshes with the anvil. In the course of one revolution of the anvil, the material is forced from D_1 to D_2 up to the slope, after being worked upon by each successive pinion in turn. The pinions therefore constitute the various stages of the process.

5. MORPHOLOGY OF FUFU POUNDING

The morphology of Fufu pounding is depicted in Fig. 11 for the two principal actions, which past

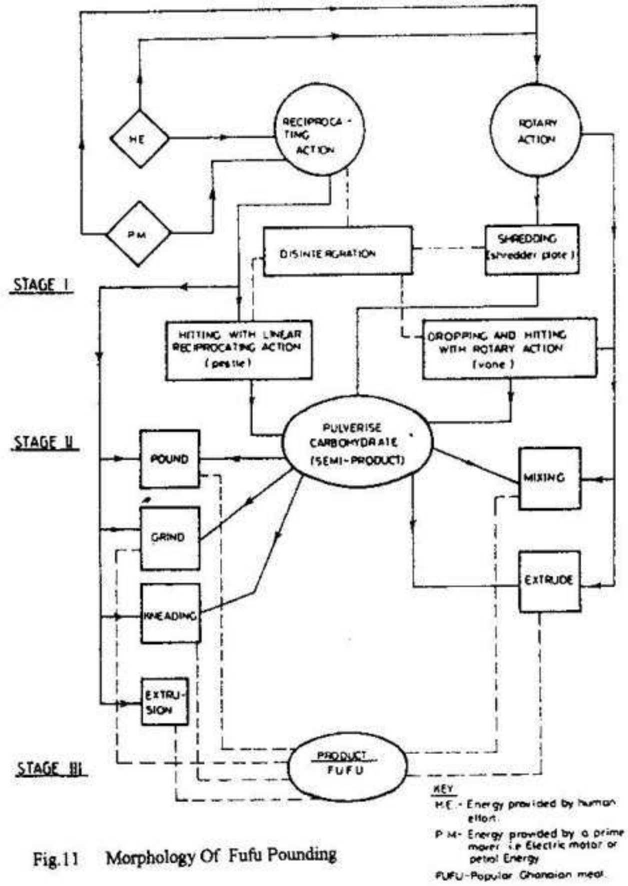

Fig.11 Morphology Of Fufu Pounding

inventors sought to utilise in their designs, namely, the reciprocating and rotary actions. With reference to Fig. 11, the particular action is produced by energy provided by either Human Effort (HE) or by a Prime Mover (PM) such as an electric motor or petrol engine.

By a very complex mechanism of hitting/smashing /grinding, aided by mixing or kneading, the actuated member (pestle or vane) disintegrates and pulverises the foodstuff in the first stages of pounding.

This break-up of foodstuff into minute particles is the most crucial stage of pounding. In fact, the extent of pulverisation determines the degree of pounding and consequently accounts for the quality of the final product, which is usually recognised by Ghanaians to be its consistency and plasticity.

It is noteworthy that every available product of Fufu powder on the market has been produced into very smooth or fine powdery form ready for mixing with warm water in order to yield the consistency required of Ghanaian Fufu. Therefore, the obvious inference is that, for any mechanical unit to be successful in producing Fufu to meet Ghanaian taste or standard, it must be capable of pulverising the foodstuff in a wet state to a very fine powder in the pulverisation stage. Hence, pulverisation is the key to successful pounding by a mechanical means.

6. FAILURE OF PAST MECHANICAL UNITS

6.1 Main Reasons for Failure

Most of the past mechanical units failed apparently due to the inherent problems of each device pointed out in Ref (1), including vibration, noise, etc. Besides these drawbacks, the failure of these units may be attributed to two main basic problems, namely:

1. Dogged pursuit of the reciprocating principle of the indigenous approach.

2. The difficulty of providing sufficient energy for pulverisation.

It is obvious from the many past mechanical designs of Fufu machines that many inventors religiously attempted to duplicate rather too precisely the reciprocating motion of the indigenous approach. The reciprocating motion is capable of producing the desired results in the indigenous situation mainly due to the human intervention.

A close observation of the indigenous pounding process reveals clearly that, the pestle's human operator gauges and hits only the portions of the foodstuff widely spread in the mortar that would produce the optimum effect of smashing. Secondly, the human kneader also simultaneously quickly grabs and positions for the pestle holder (i.e. the pounder) only the portions of the spread foodstuff which he or she deems to require the most immediate attention; again, the kneader picks and throws out undesirable lumps with such alacrity. This underscores the important difference between human endeavours and mechanical machines; the human being can discriminate with due advantage while the mechanical unit generally cannot except by the introduction of costly complexities in the design.

The second issue of power requirements for pounding is so fundamental that it is without doubt the crux of the design of the mechanical Fufu pounder. Any shortcomings which tend to negate adequate provision of power for pounding immediately defeats the efforts of the best designs.

6.2 Centrifugal Units

The unwavering pursuit of the reciprocating motion to produce pounding prevented past inventors of the Fufu machine from recognising the tremendous potential of the centrifugal motion in producing the necessary power required for pulverising the foodstuff. Indeed, the Nigerian/Japanese yam pounder, based on the centrifugal motion, had been on the Nigerian market long enough to have offered past inventors the much-needed direction and re-orientation from the dogged adherence to and copying of the reciprocating motion of the indigenous approach. This was never to be the case until the advent of a very successful Fufu Machine designed by the authors, called KEDOAN. The Nigerian Yam Pounder and the KEDOAN are the subject of another scientific paper on Fufu Machines.

7. CONCLUSION

Attempts by Ghanaian engineers and technicians at producing a mechanical device to replace the commonplace indigenous mortar-pestle arrangement for pounding Fufu have continued somewhat unrelented since the late sixties. Most of these mechanical devices have been designed on the principle of the reciprocating action as a carbon copy of the indigenous approach with its ubiquitous reciprocating pestle. An insignificant number of Fufu pounding devices have been developed on the basis of the rotary action.

Reports indicate that these mechanical units designed to pound Fufu purely by reciprocating or rotary action have had very limited success in producing Fufu of the right consistency and plasticity desired by Ghanaians. This is so, because of their inherent difficulty of pulverising the boiled foodstuff into wet powder, which pulverisation is considered by the authors to be the most crucial phase of the Fufu pounding process by mechanical means.

It is found that, where the Fufu pounding process is completely without human intervention, the most likely successful mechanical unit is that which is capable of pulverising the cooked foodstuff into a fine wet powder prior to binding itself into Fufu. Nevertheless, yam appears to be the only foodstuff that can be pounded into Fufu, the Ghanaian version, by means of these purely reciprocating or rotary units, which significantly can only squash or mash the boiled foodstuff. The remaining three basic foodstuffs (plantain, cassava and cocoyam) have the tendency to produce food pebbles or lumps with mashing unaided by human effort. In any case, rotary Fufu pounding machines of the screw type have been apparently more successful than reciprocating machines.

Therefore, it is opined that the right direction for the design of mechanical Fufu pounding unit apparently lies towards the centrifugal machine, which has been unfortunately missed out or inadvertently ignored by past inventors. The Nigerian/Japanese yam pounder and the KEDOAN, more emphatically, have led the way for a successful pounding device for Fufu by relying on the centrifugal principle.

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