DEVELOPMENT OF A MECHANICAL GARI ROASTER

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ABSTRACT

The development of a Mechanical Gari Roaster has been the result of recent efforts by the Food Research Institute, Accra, to improve upon the traditional method of gari roasting. The Roaster employs a U-shaped stainless steel roasting pan of length 125cm and width 65cm. It also has a horizontal driving shaft and a pair of hollow shafts to which two pairs of arms set at 180^{o} apart have been welded. The Roaster uses wooden blades attached to the arms as stirrers to stir the gari. The design employs a 1.35KW electric motor prime mover running at 1420rpm. The horizontal driving shaft which drives the stirrers, rotates at 11rpm and receive its power from the electric motor via a gear reduction unit and a chain sprocket drive. A liquefied petroleum gas (LPG) stove is used to provide the required heat for roasting. Trial runs indicate that the roaster has a roasting capacity of 13Kg/Hr. However modifications are being done to increase the roasting capacity of the roaster.

INTRODUCTION

Gari is a cassava product on which the Food Research Institute(FRI) has been carrying out studies for some time now. While some of the studies have been aimed at improving the nutritional value of the product, others have been aimed at providing efficient and hygienic production processes. One of these production processes is the roasting process which has been major concern. Prior to the roasting stage, the cassava is taken through the processes of peeling, washing, grating, fermentation, dewatering, disintegrating and sieving. After roasting grading and packaging is done to complete the gari production process.

Roasting consist of gelatinization and dehydration. The two operations take place in the same roasting pan within the same time frame. Gelatinization is the cooking of the sieved cassava mash and causes the gari to attain a granular texture while dehydration causes the gari to dry.

Traditionally, roasting is done in an aluminium pan mounted on a three leg mud stove and heated with fuel wood. The women processors sit by the stove and manually stir continously using a piece of calabash or plywood as the stirrer. Initially intense heat of the stove causes the gelatinization of the sieved mash. After gelatinization the intensity of the heat is reduced if necessary to allow for dehydration. The women do this by removing some of the fuelwood from the mud stove. At the end of the roasting, the product becomes light or creamy yellow.

The traditional method has its attended problems some of which pose a health hazard[2]. Attempts made at improving the roasting technology in order to enhance the efficiency and also to overcome the problems associated with the traditional method has yielded results. Out of these attempts improved stoves for roasting has been developed. These are being used at the Cassava Processing Demonstration Unit (CPDU), Pokuase of the FRI under the Council for Scientific and Industrial Research/ African Regional Center for Technology(CSIR/ARCT) project[4]. A planetary grain and legume roaster was also used for roasting gari on trial bases with the objective of assessing its efficiency in roasting and also to develop a modified design that will effectively roast gari[3]. Base on the results of these trials a planetary roaster has been designed and submitted to the CSIR/ARCT project for funding to develop the roaster.

The mechanical roaster design concept was first developed by Messrs Dzokoto and Opoku all of the Industrial Research Institute, Accra. Even though after a series of trial runs the roaster could not produce any good product, the design concept in itself was an achievement.

The objective of the work outlined in this report is to further develop the mechanical roaster that will successfully and efficiently roast gari and if possible be used for drying other cassava products.

MATERIALS AND METHODS

Design Features

The mechanical roaster consists of a U-shaped stainless steel roasting pan of length 125cm and width 65cm welded in a support frame as shown in appendix 1, fig. 1. The roaster has a horizontal driving shaft which carries all the rotating parts within the roasting pan and run through the length of the roasting pan. The rotating parts are; stirrer blades, stirrer arms and a pair of driving pipes.

The horizontal driving shaft is made of hardened steel of diameter 32mm and the driving pipes are also made of galvanize iron of diameter 35mm. The driving pipes are fixed to the horizontal driving shaft by means of notch and bolts and nuts locking device. To each of the pipes are welded two pairs of stirrer arms set at 180^0. The arms are made of mild steel of diameter 18mm and length 165mm. The pipes are positioned and locked to the horizontal driving shaft such that the pair of arms on one pipe is at 90^0 to that on the adjacent pipe (appendix 1, fig. 2). The stirrer blades are made of hard wood of length 67cm, width 10cm and 3.5cm thick. Each of the blades are held tightly in a pair of U-shaped fork-like stirrer sliding pins by bolts and nuts. The sliding pins are made from a 3mm thick and 25mm wide mild steel flat bar and a 12.5mm mild steel rod. The flat bar is first bent into a U-shaped with a square base and then the mild steel rod welded at the center on the external surface of the U to form the fork-like shape. The forked ends of the pins are bolted to the stirrer blades whilst the free ends are placed in the stirrer arms with only two degree of freedom in the vertical plane. The stirrer blades together with the sliding pins are spring loaded by sets of springs inserted into the stirrer arms before the sliding pins.

The horizontal driving shaft with the moving parts is supported in a pair of 30mm diameter ball bearing at the ends of the roasting pan and bolted to the support frame. The shaft is machined at both ends to allow for its assembly to the bearings. At one end, the shaft is machined further after the bearing to permit its assembly to a 25mm inner diameter sprocket. The shaft receives power from the driving unit through a chain drive.

The driving unit consist of a 1.35KW electric motor prime mover running at 1420rpm, a V-belt drive with a driver/driven ratio of 1:2.42, a gear reduction unit with a reduction ratio of 1:53 and a chain sprocket drive of ratio 1:1 (appendix 1, fig. 3) . With these reduction units the speed is reduced from 1420rpm to give a shaft rotation speed of 11rpm. The support frame of the driving unit is bolted to the main support frame giving the roaster a total length of 190cm and width 87cm. The roaster is heated at the base by means of a gas stove using liquified petroleum gas as fuel. The lower portion of the roaster is covered with burnt bricks to prevent heat loss.

The gas stove has two long pipes serving as the burners (appendix 1, fig. 4) . The burner is set in the horizontal plane and raised above the ground on a support which is bolted to the main support frame. The two burners are connected into one unit by two 90^0 bends and a "T". Another 90^0 pipe bend connects the unit to the fuel-air mixing chamber to which is welded a gas control nozzle. The fuel-air mixing chamber has an air control guide which is adjusted to obtain the correct flame on the burner. The differences between the first design concept developed by Messrs Dzokoto and Opoku and the one discussed in this report are stated in appendix 4.

The roaster has a gate at the bottom end which remains closed when in operation, but is opened at the end of the roasting period for the gari to be scooped out manually through the gate. Before the gari is scooped out the stove is put off and the motor is stopped.

Trial Runs

Trial runs were carried out to determine the roasting capacity, the stirring rate, the feeding rate and the quality of gari produced. For some of the trials the inside of the roasting pan was smeared with edible oil about 10ml. The stove was then lighted and set at almost full flame with simultaneous adjustment of the air control guide to get blue flame which signifies correct fuel-air ratio mixture. The roasting pan was pre-heated and the temperature at the base was measured with a thermocouple. The motor was then started and the mash was fed into the roasting pan spreading it along the length of the roasting pan. The quantity of dough fed into the pan was varied for the different trial runs to determine a suitable feeding rate. When the gari was well roasted the roasting time was recorded and the stove put off whilst the motor was allowed to run for a further time of about five(5) minutes, to allow the roasting pan to cool. The gate was then opened and the gari was scooped out with a scraper.

Quality Determination

To determine the quality of the gari produced, the following tests were performed:

Moisture

The moisture content of the mash was determined by the oven dry method using 5gm sample at 105^{0}C for four(4) hours[1].

Colour

This was determined by visual examination against the standard colour of light or creamy yellow as given by Ghana Standard Board in the Ghana Standard for gari.

Swelling Capacity

A100ml measuring cylinder was used in determining the swelling capacity. The measuring cylinder was filled with gari up to the 25ml mark and then filled water up to the 100ml mark and inverted a number of times to ensure proper mixing of the gari and water. The mixture was then allowed to settle and swell to a constant volume. The swelling capacity was calculated as the percentage increase in volume[5].

Particle Size

A nylon sieve of about 1.25mm aperture size used for grading gari at the CPDU, was used to determine the particle size. It was calculated as a percentage of particles which passed through the sieve.

RESULTS AND DISCUSSIONS

Operating conditions obtained from the trail runs are indicated in Table I, appendix 2.

Stirring Rate

During roasting the stirrers stir the dough continuously throughout the roasting period. The stirring action prevents the burning of the dough as well as the formation of lumps. After the first few trial runs it was detected that the product was not well gelatinize but dry. This resulted from the fact that the retention time for the dough was small and as such had little time in contact with the base of the roasting pan to permit enough heat absorption for the dough to get gelatinize. With a rotation speed of 11rpm, the stirring rate was 22rpm. It means therefore that with a stirring rate of 22rpm, the gari could not gelatinize. As a result subsequent trail runs were performed with two stirrers, one on each of the driving pipes. This gave a stirring rate of 11rpm just as the rotation speed of the horizontal driving shaft. All the products obtained from the roaster with this set up was gelatinized and dry. The only time the gari was not gelatinized was when the roaster was over loaded with cassava mash. The stirring rate was thus determined to be 11rpm.

Roasting Capacity

The roasting time for the different weights of sieved mash are recorded in Tables II and III, in appendix 2. These values were used to calculate the roasting capacity using the formula:

$$\text{Roasting Capacity Kg/Hr} = \frac{\text{Weight(Kg)}}{\text{Time(min.)}} \times \frac{60\text{min.}}{1\text{Hr}}$$

The average roasting capacity was determined to be 13Kg/Hr.

Average Weight Per Batch

The variation of weight of the sieved mash helped to determine the quantity that could be roasted per batch. It was observed that for batch weights of more than 6Kg, the product could not gelatinize.

Roasting Pan Temperature

It was further observed during the trail runs that for roasting pan base temperature of more than $95^{O}C$, the first portion of dough fed into the roasting pan got burnt. On the other hand, at temperatures bellow $85^{O}C$ the product gets dry and does not gelatinize. The temperature range necessary to obtain good products was therefore 85 to $95^{O}C$. These are shown in Tables II and III together with the pre-heating time required to attain the specified temperature range. This is based on the condition that the stove is set at almost full flame.

Feeding Rate

Initially the sieved mash was fed into the roasting pan in relatively large quantities. This resulted into the product forming big lumps that could not dry fully. The feeding rate was varied for the other trials and the suitable one determined is recorded in Table I.

Roasting Process

Table II shows the result of trials performed with the inside of the roasting pan not smeared with edible oil while Table III gives the results for trials performed with the roasting pan smeared with cooking oil. Roasting without the roasting pan smeared with cooking oil, caused the dough to stick to the roasting pan. This was manually scrapped during the roasting process and resulted in products that were of comparatively bigger particle size. On the other hand when the roasting pan was smeared with oil, the roaster yielded products of a much more acceptable particle size. That explains the difference in particle size values recorded in Tables II and III.

Swelling Capacity

From the specification for gari stated in appendix 3, the product should swell about three times its volume when soaked in water. This implies that the percentage increase in volume should be about 200%. All the samples met the requirement of the standard. The little differences between the recorded swelling capacity values may be attributed to the degree of gelatinization and dryness of the products.

Particle Size

The degree of lumpiness of the sample of products recorded in Table II has been explained earlier on. From Table III however, the average percentage of gari passing through a 1.25mm sieve is 80.6%. At the CPDU, the average percentage of gari passing through a 1.25mm sieve is about 83%. Comparing the results, the particle size of products obtained from the CPDU and that obtained from the mechanical roaster are almost the same.

Colour

The different colours obtained may be due to the different varieties of cassava used, but further studies will have to be carried out to establish this fact. The burning effect of some of the particles produced the dirty cream colour.

Moisture

The moisture content of the sieved mash was determined to be 51.6%.

Other Trials

The roaster was also used to dry cassava foofoo(lafun) a local Nigerian food. In this case the stove was set at a comparatively lower flame and thus provide lower temperatures necessary for drying the product.

CONCLUSION

Results from the trail runs indicate a successful roasting and drying ability of the mechanical roaster. To successfully use the roaster however the following instructions need to be followed:

i. The inside of the roasting pan must be smeared with a little amount of oil.

ii. The roaster must be pre-heated for about three(3) minutes or to a temperature between 85 to 95^{0}C with the stove set at almost full flame.

iii. The dough should be fed into the roasting pan in amounts of about 400-500gm at a time spreading it along the length of the roasting pan. This should be continued with few minutes interval until all the dough for the batch has been fed into the roasting pan.

iv. When the product is fully roasted the stove should be put off but the electric motor should be allowed to run for about five minutes before collecting the product through the gate.

v. When using the roaster as a dryer, pre-heating the roasting pan is not necessary and it is not required to smear the roasting pan with cooking oil. In this case immediately the stove is lighted and set at medium flame level, the electric motor is started and feeding of the dough into the roasting pan follows. Steps iii. and iv. above then follows.

vi. In all cases, whether roasting or drying the moisture content of the mash should not be more than 51%.

One important fact that was observed during the trial runs was the ability of the roasting pan to be heated up very fast and in the same way loses its heat very fast. This was due largely to the thickness of the roasting pan. If the heat retention ability of the roasting is improved the roasting capacity of 13Kg/hr could be increased. It is highly possible that using a relatively thicker roasting pan will help to achieve this objective. This idea will be researched into fully in future studies. Also the cost benefit analysis will be looked at.

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APPENDICES

Appendix 1

1. Roasting Pan
2. Horizontal driving shaft & Stirring assembly
3. Electric mottor & Power transmission assembly
4. L.P. Gas stove assembly.
5. Bearings
6. Gate.

FIG.1 MECHANICAL GARI ROASTER (Cut view)

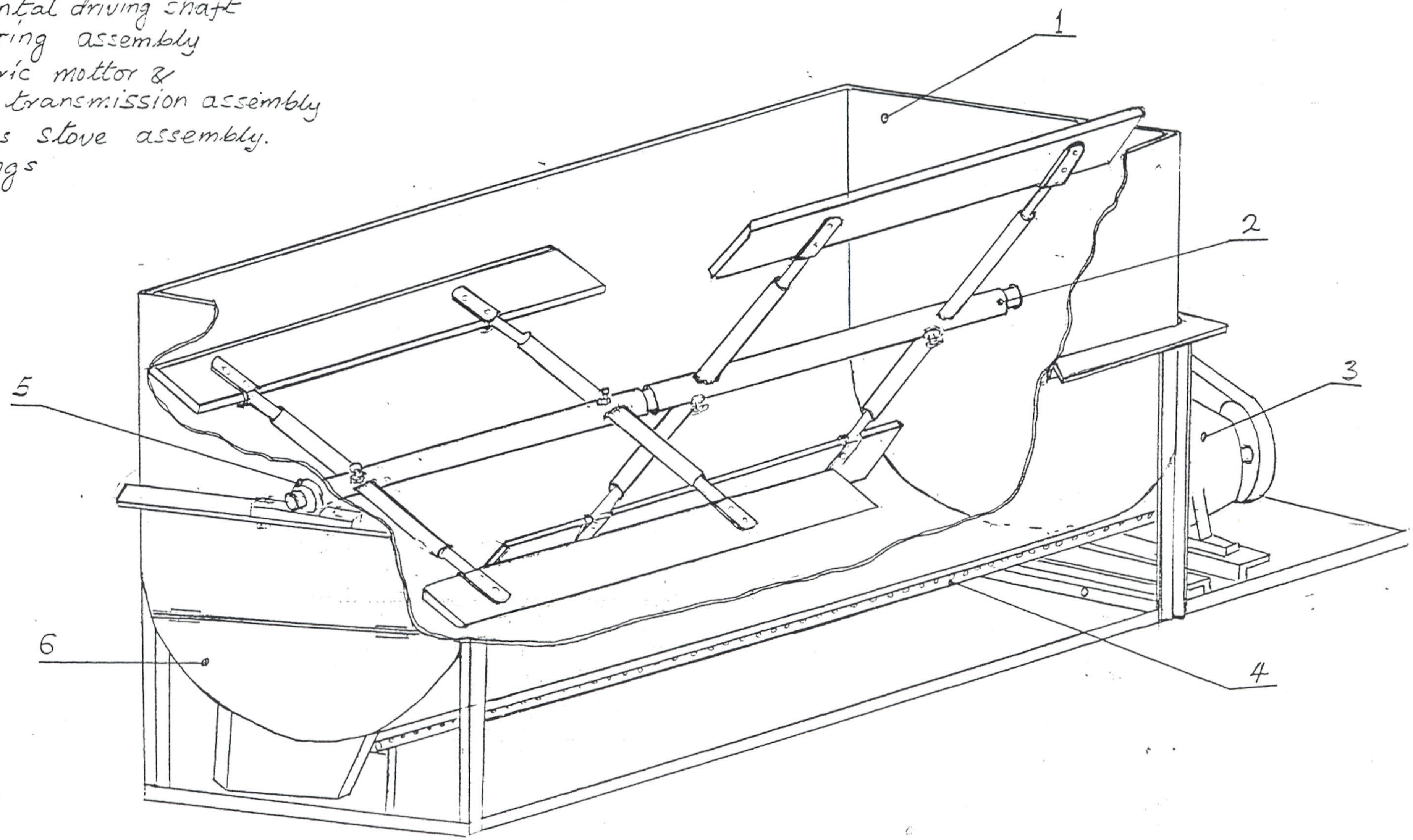


FIG 2. HORIZONTAL DRIVING SHAFT & STIRRING ASSEMBLY

1. Horizontal Driving Shaft
2. Driving Pipe.
3. Stirrer arm.
4. Sliding Pin
5. Stirrer blade
6. Spring.

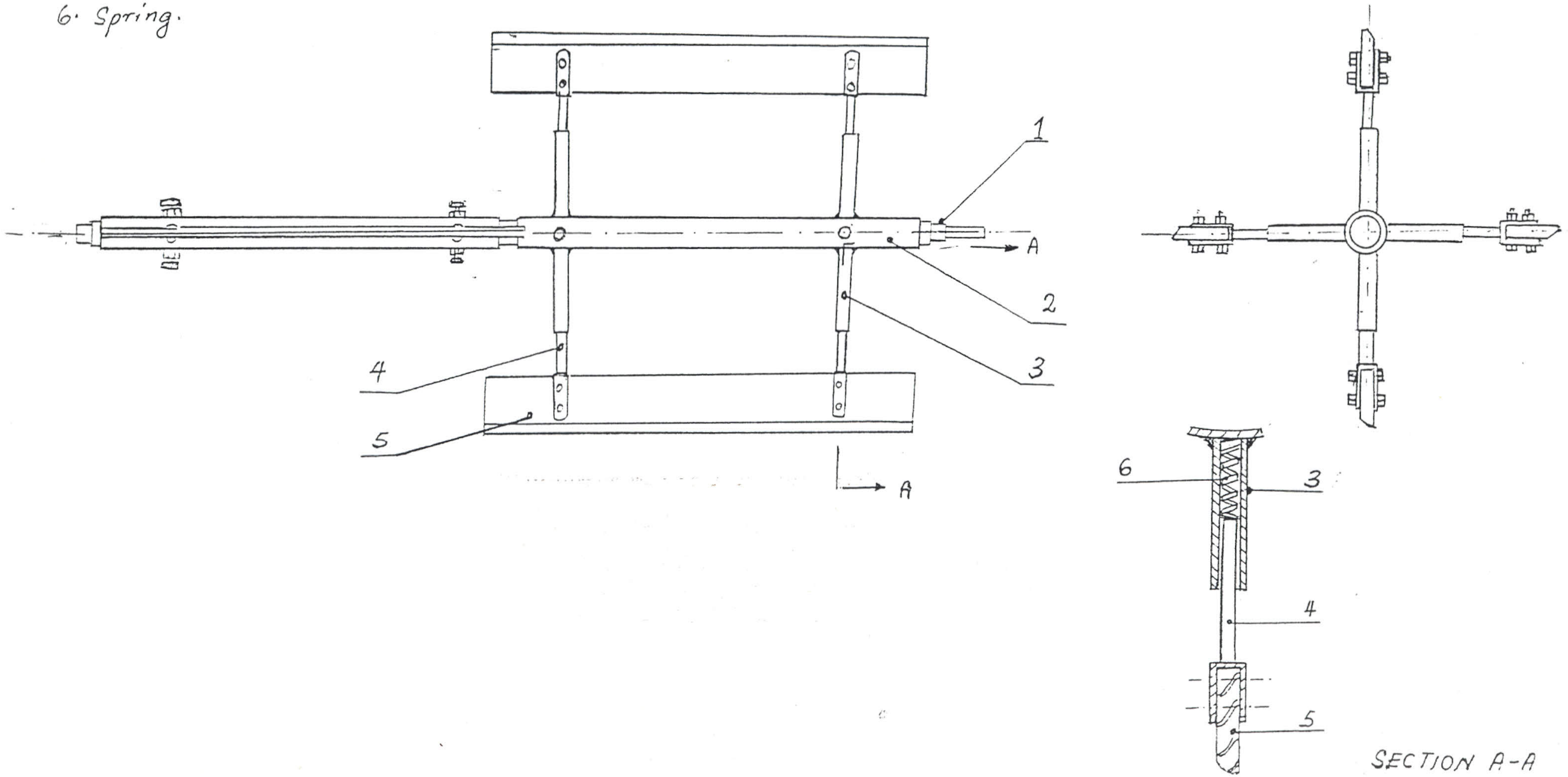
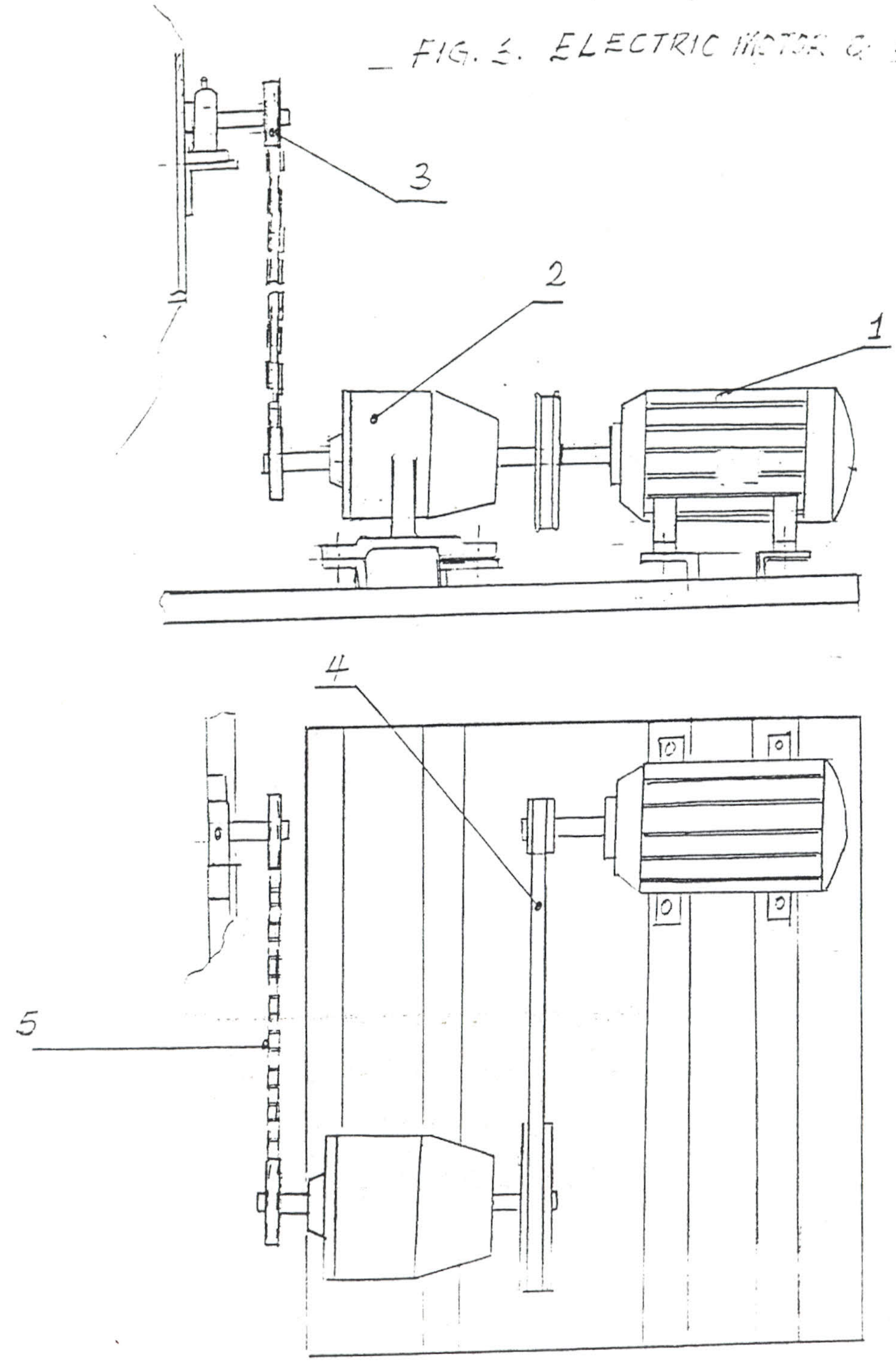
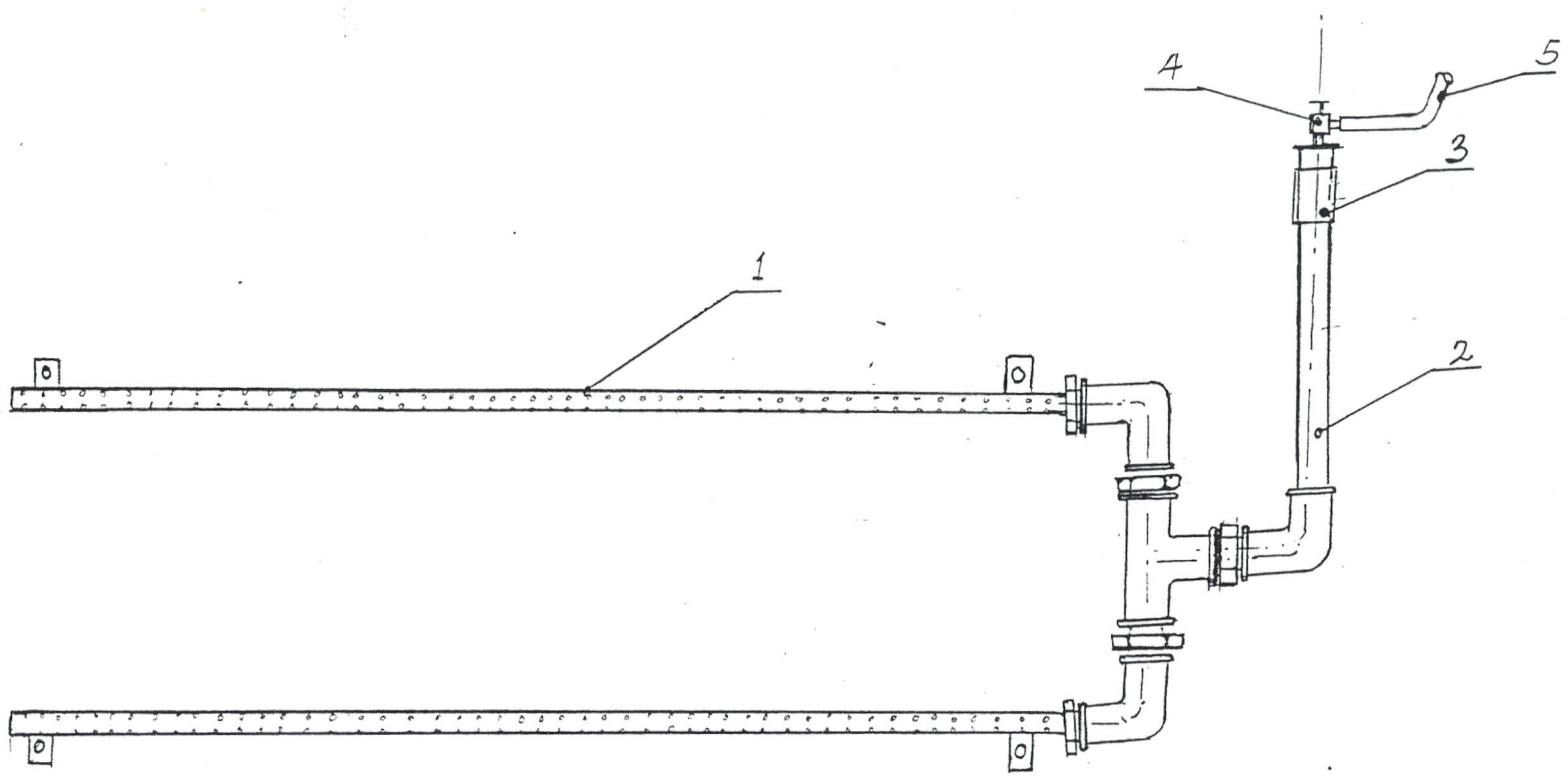


FIG. 3. ELECTRIC MOTOR & DRIVING ASSEMBLY.



1. Electric motor
2. Reduction gear unit
3. Horizontal Shaft sproket wheel & shaft
4. Driving belt
5. Chain sproket

FIG 4. L.P. GAS STOVE ASSEMBLY



1. Bunner pipe
2. Fuel & Air mixing Chamber Assembly
3. Air Control Slide
4. L.P. Gas Control Nozzle
5. L.P. Gas hose.

Appendix 2.

Table I: Operating Conditions and Capacity

Stirring rate	11rpm
Roasting capacity	13Kg/hr
Average weight roasted per batch	5.5Kg
Roasting pan temperature	85 - 95°C
Feeding rate	400 - 500gm at a time

Table II: Pre-heating time, Roasting Pan temperature, Weight of sieved mash, Roasting time, Swelling Capacity, Particle size and colour of Gari.

_____ Roasting Pan Not Smeared With Oil.

Pre-heating Time (min.)	Roasting Pan Temperature (^{o}C)	Weight of Sieved Mash (Kg)	Roasting Time (min.)	Swelling Capacity (% increase in volume)	% of Particle Passing Through 1.25mm Sieved	Colour
3	92	6	27	196	65	Creamy white
3	86	5.6	25	204	66.7	Creamy white
3	95	5.5	24	204	71.4	Creamy white
2	85	5.8	26	192	58.3	Creamy

Table III: Pre-heating time, Roasting Pan temperature, Weight of sieved mash, Roasting time, Swelling capacity, Particle size and Colour of Gari.

_____ Roasting Pan Smeared with Edible Oil.

Pre-heating Time (min.)	Roasting Pan Temperature (^{o}C)	Weight of Sieved Mash (Kg)	Roasting Time (min.)	Swelling Capacity (% increase in volume)	% of Particle Passing Through 1.25mm Sieve	Colour
3	88	5.5	24	228	81	Creamy yellow
3	92	6.0	26	228	80	Dirty Cream
2	86	5.0	25	204	82	Dirty Cream
3	91	3.0	15	200	80	Creamy yellow
3	95	5.6	24	204	80	Creamy

Appendix 3

By Ghana standard[5], the quality specifications for gari is stated as follows:

i. The product should be light or creamy yellow in colour.

ii. The product should be dry and crisp.

iii. The particle size of the product should be nearly uniform.

iv. The product should swell to about three times its volume when soaked in water.

v. The product should be clear and not contain dirt or any extraneous matter.

vi. The product should be slightly sharp and sour rather than bland to taste without any peculiar odour.

vii. The product preferably have a low fibre content.

viii. The cyanide content of the product should not exceed 20ppm.

Appendix 4

Differences between the first design concept developed by Messrs Dzokoto and Opoku and the one discussed in this report.

Dzokoto and Opoku	Attiogbe and Gyato
i. Driving shaft size____ 25mm	i. Driving shaft size_____ 32mm
ii. Driving shaft speed____ 27rpm	ii. Driving shaft speed____ 11rpm
iii. Uses brass dry bushing.	iii. Uses ball bearing.
iv. Tapering pins were used to lock the driving pipe to the driving shaft.	iv. Notch bolts and nuts were used to lock the driving pipe to the driving shaft.
v. Uses o.75KW electric motor.	v. Uses 1.35KW electric motor.
vi. Has 2 sets of four stirrer blades each latter reduced to three each.	vi. Has 2 sets of two stirrer blades each but uses one each.
vii. Uses fuel wood and when using biogas employs four small burners.	vii. Uses one unit LPG gas stove which stretches over the length of the roasting pan
viii. Comparatively shorter sliding pins.	viii. Comparatively longer sliding pins.