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EXPERIMENTAL WORK AND OVERSEAS TRIALS OF A CASHEW NUT PROCESSING PLANT DESIGNED AND BUILT BY THE TROPICAL PRODUCTS INSTITUTE [1]

by

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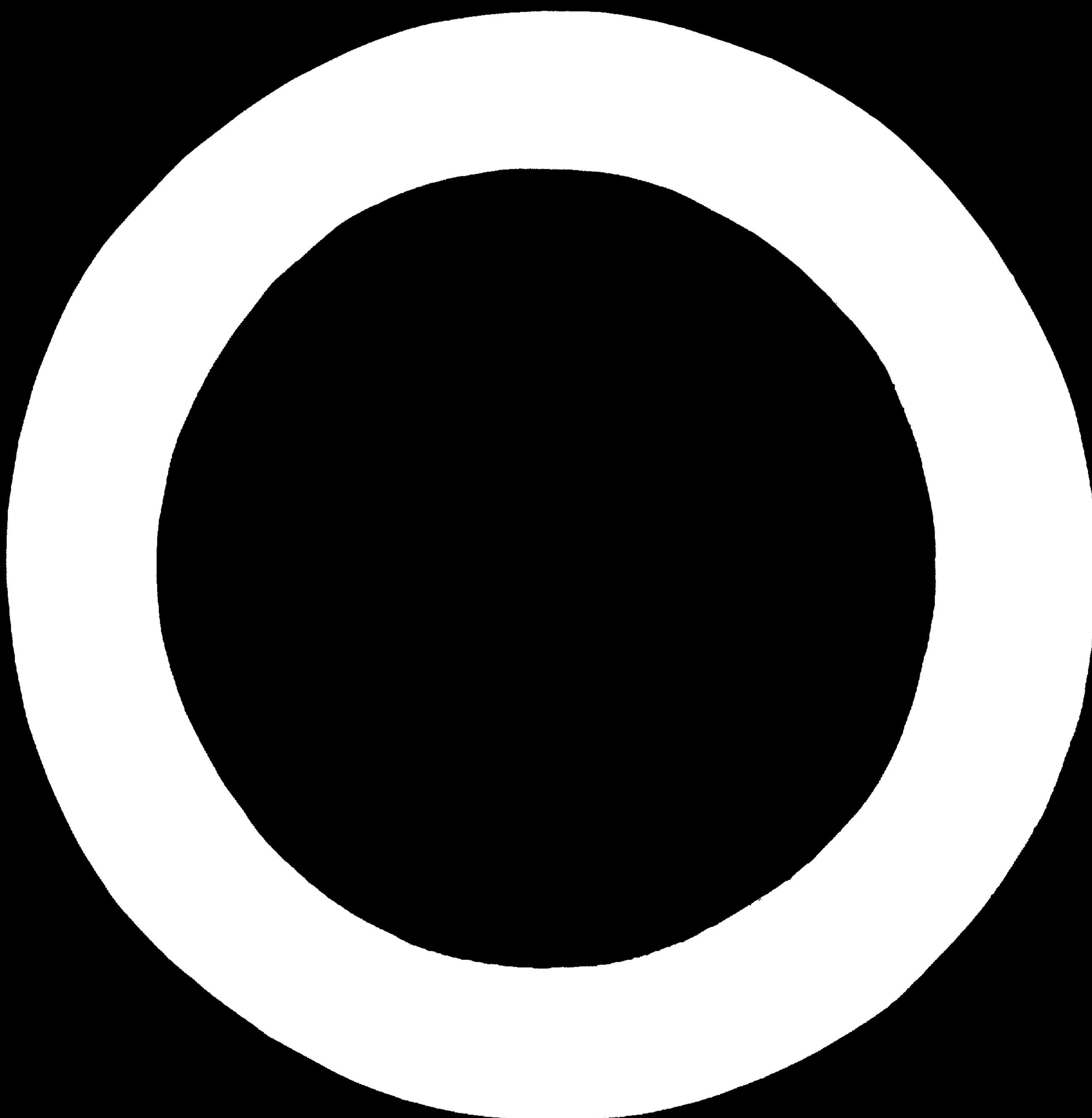

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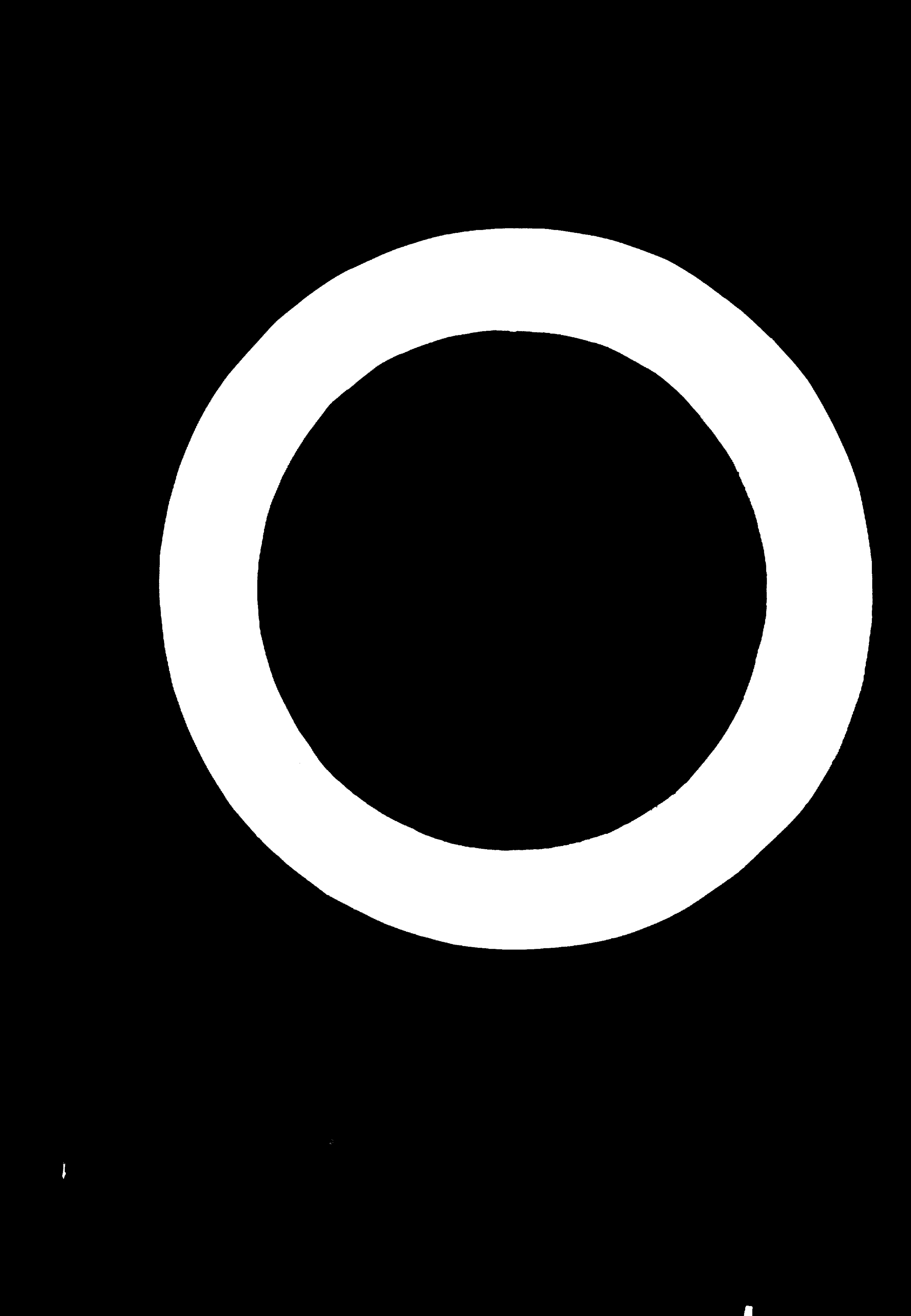


THE T.P.I. CASHEW DECORTICATION PLANT

The cashew nut (Anacardium occidentale) is a tree fruit which grows in coastal areas roughly within the tropics of Cancer and Capricorn. Plate 1 shows the nut hanging from the cashew apple, and it is harvested when the apple and nut fall from the tree from March to July. In some areas there is a second small crop from October to December. The shell of the nut is cellular and contains cashew nut shell liquid (20% - 25% by weight). Cashew nut shell liquid (known as CNSL) is toxic, 10% of it consists of anacardic acid and it can be polymerised by heating. The shell is soft enough to be difficult to remove from the raw nut - in other words it will not crack in the raw condition. Furthermore the cashew nut shell liquid within the shell is more toxic when the nut is raw than if it has been heated.

The kernels have been eaten for many years and the accepted method of removing the kernel has been to roast the nut until the shell becomes crisp and to subject it to three or four taps delivered by a piece of wood in the plane of cleavage. This splits the shell and enables the kernel to be taken out. Cracking by this means is unhygenic and the people who carry out the operation often suffer considerably because the CNSL even after the roasting process tends to attack the skin of the operator's fingers.

Over recent years there has been an increasing demand for cashew kernels and they have become a very lucrative export to the more sophisticated countries. This has caused the countries able to grow cashew to increase their production, but in many cases the increase has been limited by the number of skilled operators required to carry out the decortication process.

A machine operated method of decortication has been in existence for some time. It is quite efficient but expensive both in capital cost and in the use of labour. This is because each nut, after roasting, is cut individually around the shell, thus releasing the kernel. Factories using this type of equipment have been quite large, processing 10 to 15,000 tons of raw cashew per year and have usually been situated in a large town or city. There are many people who consider that development should start

SECTION OF
A CASHEW NUT

CASHEW APPLES
AND NUTS

PLATE 1:

in the villages and that a small, easily operated, mechanical plant should be available to allow villages in the cashew producing areas to process their own nuts on a larger scale than before.

About six years ago the Tropical Products Institute were asked to investigate various means of decorticating cashew nuts using machine operating methods and to devise a simple and easily operated system. The method of opening or cracking the nut was the first thing to be given consideration and various systems were tried and discarded on the grounds of cost.

We decided that the simplest possible method was to use impact force to break the shell open and that the best way to apply that force was to drop the nuts on to a rotating disc fitted with vanes, so designed that centrifugal force ejected the nut on to target plates arranged around the periphery of the cracker. The velocity required at impact was found by experiment to be 19.6 m/sec. for an average nut weighing 6 gms. Having found this terminal velocity, we then designed a rotor, and found the optimum position for the target plates, setting them in a circular configuration around the rotor, and overlapping each plate to ensure that misses did not occur. Experimental work showed that these target plates were most effective when inclined at an angle, and that this reduced the average number of cycles required to decorticate a nut. High speed cinematography was used to ascertain the path of the nut as it left the rotor, the way in which it struck the target plate and the trajectory of nut shell and kernel following this impact. This work enabled the cone, fitted below the decorticator to be designed so that kernel damage was avoided.

This early work was carried out using an electrically heated roasting bath to make the shells of the nuts crisp enough to shatter after several impacts. The bath was fitted with a conveyor belt which carried the nuts beneath the surface of the 90 litres of CNSL held in the bath which could be thermostatically controlled to temperatures ranging from 170°C to 210°C. We decided that the roaster should be constructed of mild steel and that stainless steel would be used, where this was impracticable sheathed heating elements 61 cms long were fitted to supply the necessary 12 kilowatts of heating.

During this experimental stage there was a decided tendency to soak the nuts too much and this meant that after 24 hours of humidification (when the soaked nuts were kept in an ambient atmosphere of 100% R.H. and 30°C), the moisture content of the shell and kernel was 24.6% and 18.9% respectively. Later work showed that soaking times from 4 minutes to 12 minutes were all that was normally necessary for Kenyan nuts which were one year or less in store, and that it was essential to keep the moisture content of the kernel down to approximately 8% to obtain a good white kernel after roasting and to avoid the "bluing" which occurs due to tannin in the testa of a moist kernel. Of course there is a considerable need to obtain the correct moisture content of both shell and kernel if an impact method of cracking is used. It is essential to obtain a brittle shell which will break in the minimum number of cycles and a fairly elastic kernel which will withstand the impact needed to break the shell open and will remain whole.

A great deal of time was spent in determining optimum moisture content of shell and kernel, the best roasting temperature for those moisture contents, and the correct cracker speed. Each trial was aimed at establishing process conditions which would give the maximum number of white, unscorched kernels from a batch of 100 nuts, the nuts having previously been graded so that they were all of 13-15 mm girth.

We had found that moisture contents of 10% to 12% in the shell and 8% to 10% in the kernel gave the best results with roasting temperatures of 180-185°C and roasting times of 1.4 to 1.8 minutes. Whilst these tests were proceeding, several spurious results were produced because the roaster did not appear to be roasting properly. We found that because we were only roasting relatively small batches of nuts, with consequent small cashew nut shell liquid make up, and relatively long heating up, and cooling down times, the viscosity of the cashew nut shell liquid in the roaster tank had increased very considerably from .234 $N./m^2$ to .85 $N./m^2$. There was very poor circulation, and very high temperature differentials which meant that the nuts were not roasting properly.

We had now reached the stage which required the design and construction of the first decortication pilot plant. After some consideration we decided that it should consist of a conveyor feeding roasted nuts to the top of the centrifugal cracker, the uncracked nuts, kernels and shell being taken from the cone at the bottom of the cracker, by a further conveyor to a screen. Whole nuts passed over the top of the screen, shell and kernel passed through the screen and were separated by means of an air elutriator. The whole nuts left the top of the screen and were guided on to the feed conveyor, where they joined the new feed to the cracker and were recycled (see Plate 2). Some difficulty was experienced in selecting the screen to be used for the separation of whole nuts from kernels and shells. We had thought that a vibrating screen would be the best thing to use and collaborated with a firm to have one made for our plant. This screen did not function at all well. In the first instance only the middle third of the screening was vibrated sufficiently to prevent blinding. To ensure that the outer sections were vibrated properly it was necessary to remove the cover from the top of the screen. This increased the noise level in the immediate vicinity to 93 d.b., and it was still noted that some kernels and shell passed over the top of the vibrating element. The manufacturers were called in, and they modified the vibrators by adding additional out-of-balance weights to the motors. This increased the noise level, but the screen did work very efficiently. However, the vibration was too intense for the framework, and, after some fifteen hours of running, we had to shut down because 16 cracks had appeared in welds and parent metal of the supporting structure. In view of the programme, no more time could be spent in modifying this piece of equipment and a second hand Simon Barron reciprocating screen was purchased. A variety of different screens and screen wire shapes were tried, but it was found eventually that a woven mesh of 1.6 m/m diameter mild steel wire with openings of

PLATE 2: First decortication unit erected in temporary laboratories prior to move to Culham.

1.91 cm by 1.27cm was by far the most effective. It was also necessary to modify the suspension of the mesh frame to give a small flick at the top of the return stroke. This was done by mounting small rubber blocks between the main screen support structure and the leaf suspension springs. A series of trials carried out using this type of screen showed that queuing and blinding did not occur, and it was considered that this was the simple and economic device which we required for this part of the plant. Our method of deciding upon the dimensions of screen to be used was mainly empirical and experimental. We knew that each nut required approximately 7 cycles before the kernel was released, and we were designing for throughput of 272 kgs of raw nuts per hour or 4.53 kgs of raw nuts per minute. To allow for recycling of nuts the cracker was designed to handle a throughput of 90.5 kgs per minute, and taking residence time in the cracker, and on the screen into account, together with practical conveyor speeds and sizes, we felt that the time for one cycle should be half of a minute. The quantity of shell, kernel and whole nuts in the system when the plant reached equilibrium would be approximately 38 kgs when 272 kgs per hour of raw nuts was being processed. Conveyor widths and lengths were estimated and it was found that there would be 8.16 kgs of product on the screen at any instant. Experimental work showed that a screen of 1.52 metres x 6.08 metres would handle this quantity when reciprocating at 370 strokes/minute.

Having established the two main pieces of equipment in the decortication unit, the centrifugal cracker and the screen, it was then necessary to decide on the means of transport between them. We now knew the height of the cracking unit, and of the screen, and decided that these two items could be fed most economically by means of standard skid plate conveyors. The conveyor connecting the discharge from the cracker to the top of the reciprocating screen was 3.65 metres in length and inclined at 18° to the horizontal plane and the feed conveyor from the discharge side of the screen to the top of the conveyor was inclined at 20°, and 4.56 metres long, the belts being made of PVC coated terylene, because this material was food quality and easy to clean.

The speed of these conveyors was at 24.6m per minute, to give a fairly thin belt layer and no slip, and to keep the residence time of any one nut in the system down to the design specification of ½ minute per cycle. Separation of kernels and shell, after passing through the screen was by means of an air elutriation system, the kernels dropping through an air stream because of their greater mass, and the shell being blown up and away.

Plate 3 shows the first decortication unit when it was erected. A series of trials were carried out using various nut moisture contents, roasting times, cracker speeds and raw nut feed.

When we had started on this project it had always been considered that the decortication unit was all that was required, and that this would be part of a conventional hand-cracking factory, using nuts which were pre-processed, and roasted by the means previously in existence in that factory. The work which we had done made it quite clear that it was very necessary to obtain raw nuts of the correct moisture content prior to roasting, and that the actual roasting operation was quite critical. We, therefore, decided that our plant could not be successful unless it had its own soaking, humidifying and roasting process. It would then of course be completely independent, and could be installed in any cashew producing area as long as operatives could be trained to carry out hand peeling and grading of the kernels.

As it was our intention to make the plant as simple and as cheap as possible we decided that the soaking and humidifying should be carried out as a batch process, using standard .456 m^3 water cisterns to contain the nuts. These tanks were fitted with a perforated plate 5.24 cms above the bottom of the tank, and in the first instance we considered that the method to be adopted was to put nuts into the tank up to a given level 136 kgs, fill the tank up with water and after a predetermined soaking time (4 , 20 minutes), drain the water off to the level of the perforated plate and then leave them to humidify for 24 hours. At this stage we also considered it necessary to simulate tropical conditions by keeping the water at a temperature of

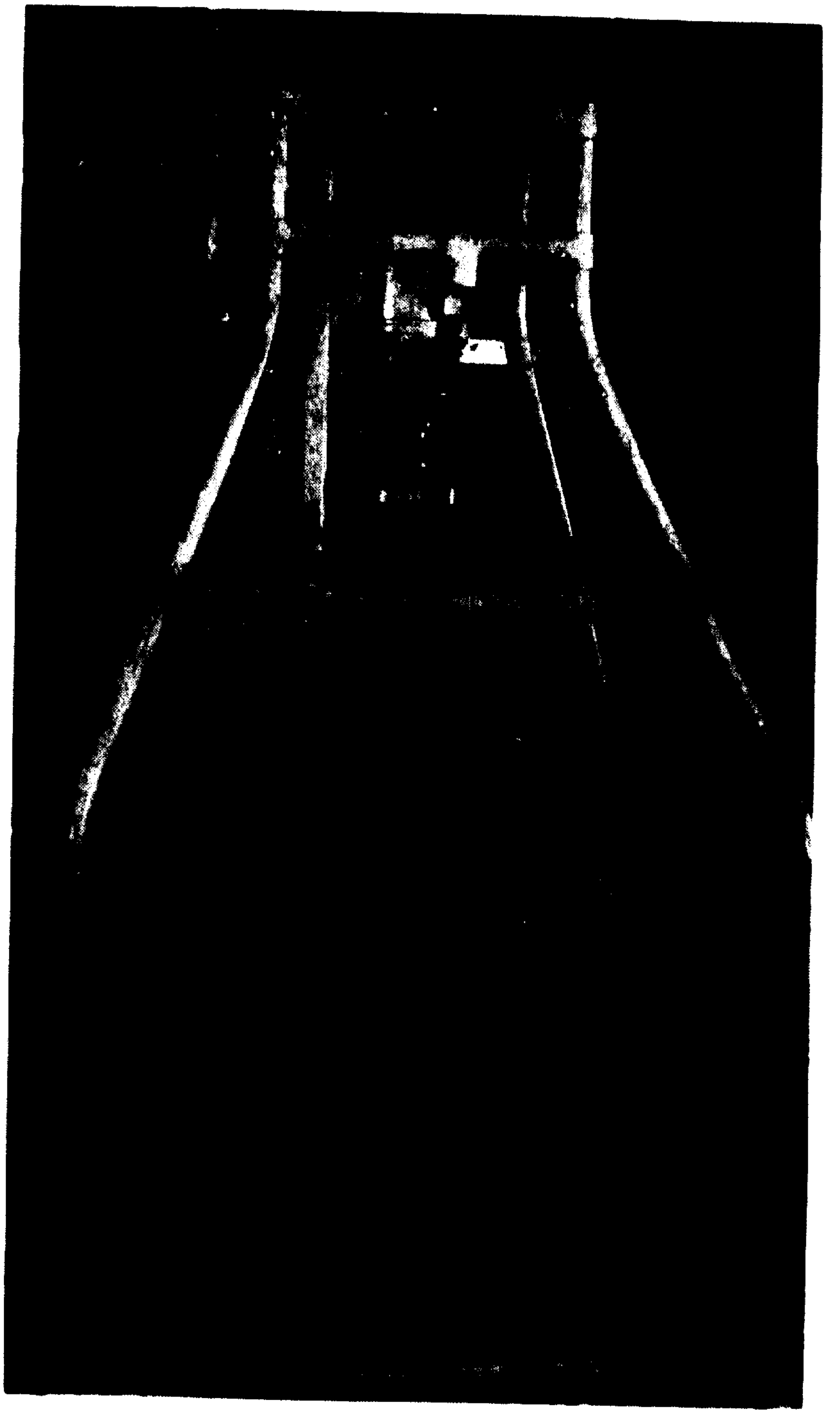


PLATE 3: First centrifugal Cashew nut cracker.

30°C by means of electrical heating elements. When the nuts were ready to be roasted the remainder of the water was to be drained off, and the tank hoisted above the feed hopper of the roaster and its contents tipped in. In fact we subsequently found this impractical and uneconomic in regard to water useage, and changed our method of charging the nuts into the tanks, and into the roaster. We required 32 tanks to contain sufficient nuts for eight hours running, these tanks being filled in sequence, and obviously had to be used in the right order to ensure that all nuts had the same humidifying period (Plate 4).

Examination of methods of roasting the cashew had been carried out when the project was in its early stages and we had already decided that the most controllable process was to use an oil bath filled with cashew nut shell liquid. We had by now decided that where possible we should make the process continuous, and therefore designed a gas fired roaster with an oil capacity of 364 litres. The cashew nuts were put into a hopper of 136 kgs capacity, and were fed on to a chain mesh belt fitted with flights at 9 inches intervals. The feed consisted of a rotating drum which when filled contained 1.59 kg of nuts, which was fitted with a speed controller and could be rotated between ½ to 1¼ revolutions per minute. This made it possible to control very accurately the quantity of nuts fed into the roaster. Twenty four 7.72 cm O/D heating tubes passed transversely through the CNSL filled portion of the tank, each tube having a gas burner fitted at one end, the other end being connected to a stack through which the products of combustion passed to atmosphere. It was realised that gas would be an expensive method of heating, but it was felt that we should start in this way, and prove the system. We could then convert to cashew shell firing when we had a little more time. The conveyor first carried the nuts over the surface of the heated CNSL, and preheated them, it then took them below the surface. They were then retained by the flights and moved along a perforated plate situated in the CNSL immediately above the heating tubes. A withdrawable sheet of mild steel was placed beneath the heating tubes to facilitate cleaning of the tank, and a 2 HP pump was

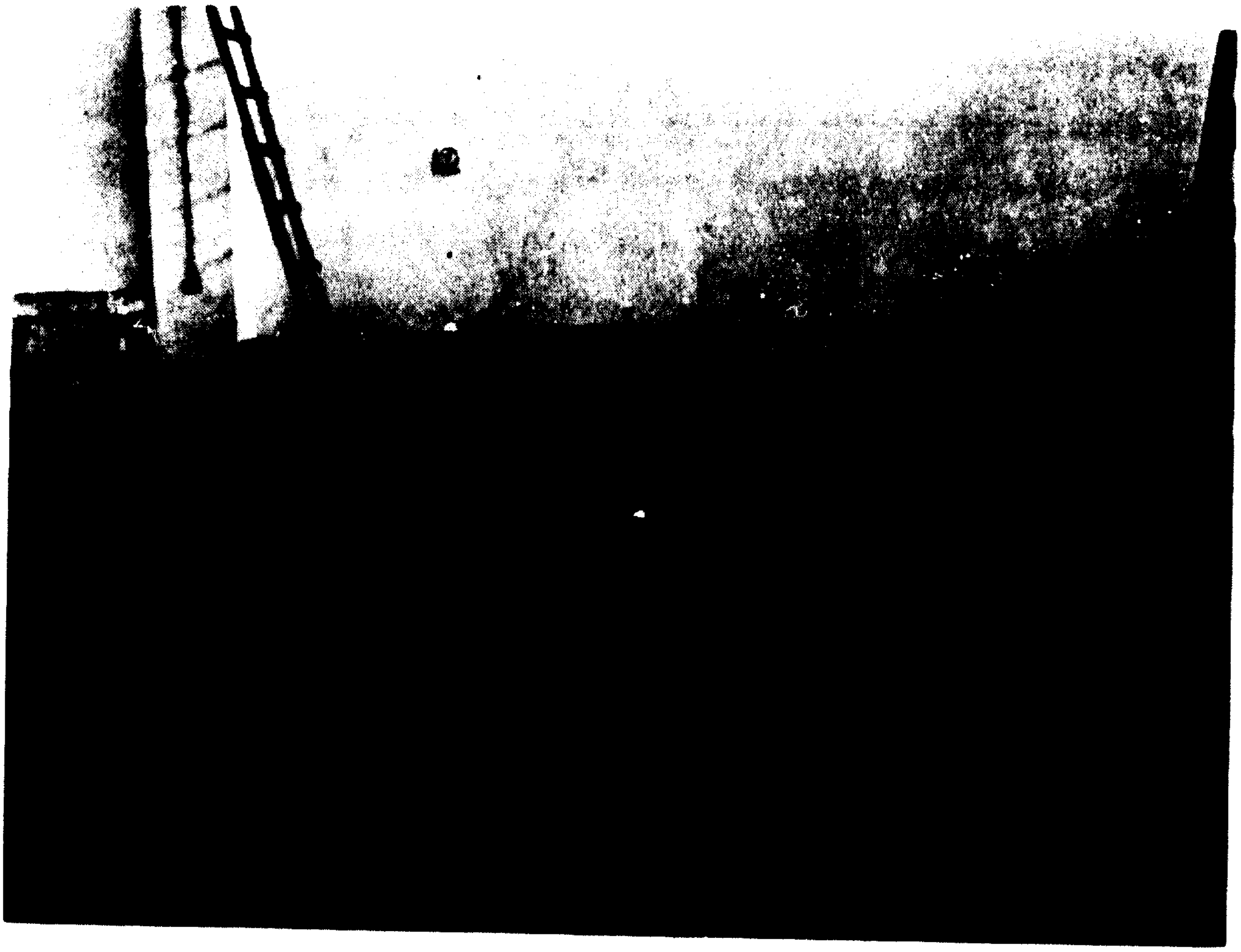


PLATE 4: Soaking and humidifying tanks as used during plant trials in Kenya.

provided for recirculation, the oil being taken from the overflow tank fitted at the discharge end of the roaster, and discharging through sparge pipes laid along the length of the bath and beneath the heating tubes. The soeed of the conveyor was controlled between 0 metres/min to 8 metres/min by a Carter gear and this gave below the surface roasting times of down to .35 minutes.

Our previous work with the small electrically heated roaster had shown how essential it was to control the temperature accurately, and also to keep the temperature of the heating surfaces as low as possible, while still attaining correct roasting conditions of 180°C. We, therefore, fitted thermocouples on selected heating tubes in three positions, in the oil bath, in the stack and also in the fume extract from the surface of the bath. These thermocouples were connected to two, six point Kent recorders. By adjustments carried out on the helical retarders fitted at the discharge end of the heating tubes and by thickening up the tubes at the burner end we were able to keep the tube surface temperatures between 220 - 230°C, and this of course is very helpful in preventing the CNSL from becoming too viscous due to overheating.

CNSL overflowed over a weir at the nut discharge end of the roaster and through a filter into a lagged overflow tank, and as previously mentioned was then recirculated by means of a gear pump. It was found necessary to pay a great deal of attention to ventilating the space above the oil to ensure that fumes were properly drawn away, with minimum heat and vapour loss, and an acid resisting axial flow fan was used for this purpose.

There is between 20% and 25% of CNSL by weight, in the shell of a cashew nut and our method of roasting released 8% of the oil, leaving approximately 12% in the shell. The oil thus produced was tapped from a point near the surface of the liquid at the forward end of the tank, using two needle valves (in case one was blocked). (See Plate 5).

It had been very obvious that an effective and cheap method of cleaning the

PLATE 5: Roaster installed in TPI laboratories at Culham, United Kingdom. When first installed was gas fired but was later modified to allow cashew shell to be used as a fuel.

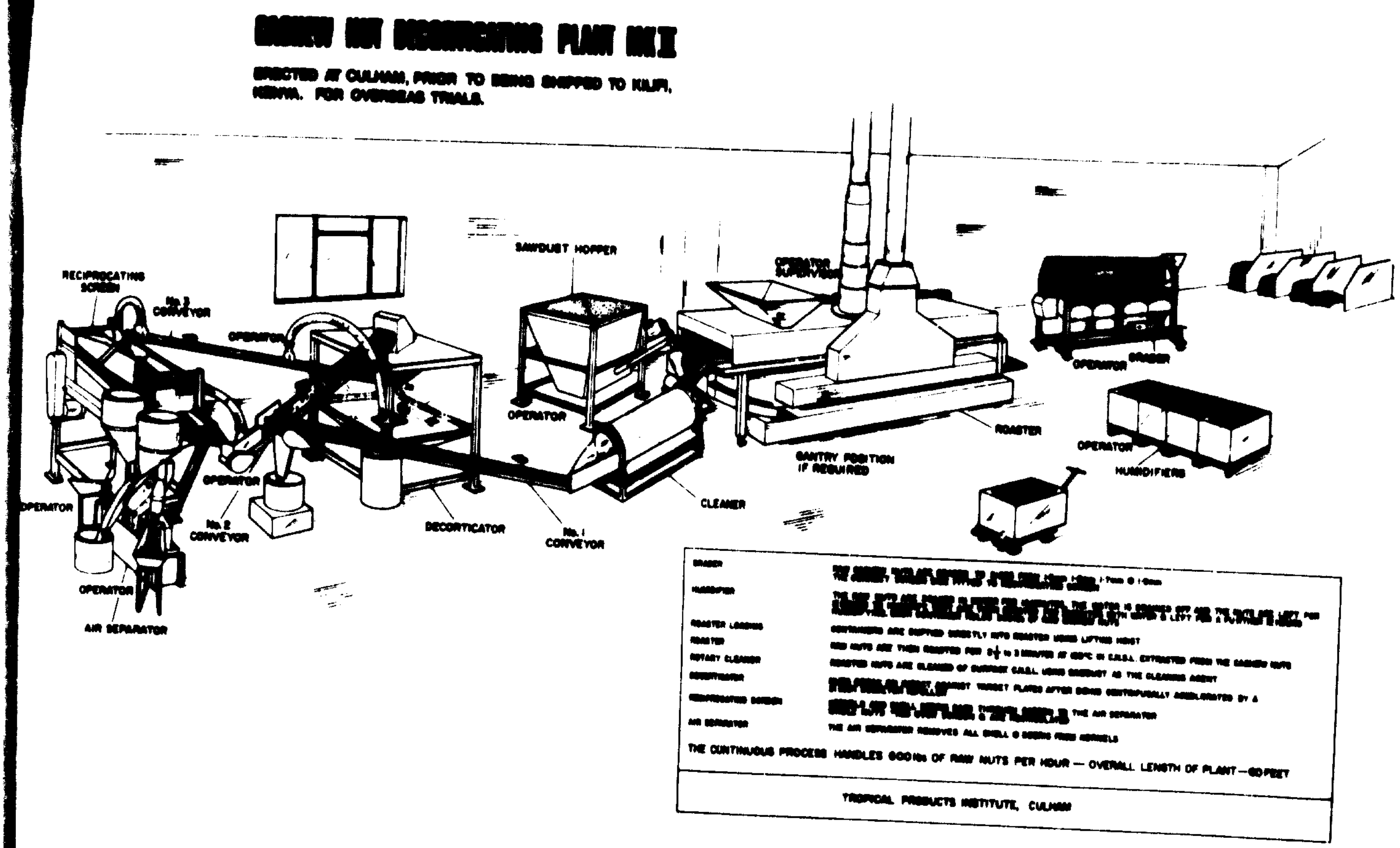
roasted nuts after they left the roaster was essential. We were also aware of the need to cool the nuts for a few minutes before decortication. We decided, therefore, to combine these two processes and designed a rotating drum (15 RPM) fitted with two internal helical guides which fed the nuts through the drum in 7 minutes. Throwers were fitted on the outer edges of the helices and an auger was arranged to feed sawdust in with the roasted nuts at 3.65kg of sawdust per hour. The nuts were thus rumbled with the sawdust and the CNSL adhering to their shells after roasting was absorbed, whilst a certain amount of cooling took place.

We realised that a certain amount of CNSL was lost using this method, but it was considered to be cheaper and certainly gave a cleaner surface than could be produced by the use of a continuous centrifuge.

Our test for cleaning efficiency was to rub a series of selected nuts against a piece of white paper and if a negligible stain was left we considered that the cleaner was working satisfactorily. We found that less than 1% of the CNSL originally on the shell, remained after the roasted nuts had been passed through the continuous cleaner. Tests were carried out with other materials such as rice hulls, and coffee parchment and these were found to be effective as a subotitute for sawdust if this waste product was difficult to obtain in any areas.

By August 1968 we had completed the whole of the design and manufacturing work and had installed the complete processing and decortication unit in our process laboratory at Culham (See Plate 6). It had been arranged that the equipment should go to Kilifi in Kenya in June 1969 and be installed in the factory of Kenya Cashews Ltd where it would be given proper field trials under production conditions, and the kernels would be marketed in the usual way. In the meantime a series of plant proving runs were carried out to ensure that it operated efficiently, and to allow us to make such modifications as were seen to be necessary prior to testing in the field. In Britain we had been using propane gas as the fuel for the roaster, but it was realised that the jets and pressure relief valves would have to be changed when we roasted using butane gas in Kenya. One of the difficulties which we encountered was

PLATE 6:



KEY:

GRADER	Raw cashew nuts are graded to sizes from 1.3 mm, 1.5 mm, 1.7 mm and 1.9 mm The correct screen size fitted to reciprocating screen
HUMIDIFIER	The raw nuts are soaked in water for 10 minutes, the water is drained off and the nuts are left for 12 hours to humidify. They are then sprayed for 3 minutes with water and left for a further 12 hours humidifying. Each container holds 100 lbs. of raw cashew nuts.
ROASTER LOADING	Containers are emptied directly into roaster using lifting hoist
ROASTER	Raw nuts are then roasted for 2½ to 3 minutes at 180° C in C.N.S.L. extracted from the cashew nuts.
ROTARY CLEANER	Roasted nuts are cleaned of surface C.S.N.L. using sawdust as the cleaning agent.
DECORTICATOR	Nuts break on impact against target plates after being centrifugally accelerated by a 21 inch diameter impeller.
RECIPROCATING SCREEN	Kernels and shell debris pass through screen to the air separator. Whole nuts pass over screen and are recirculated.
AIR SEPARATOR	The air separator removes all shell and debris from kernels.

in obtaining exact figures of the breakage rate of kernels in the plant. We had insufficient staff to carry out large scale sorting operations and had to rely on snatch samples of kernels being taken from the kernel discharge of the air elutriator, counting these to estimate our whole kernel efficiency. We used thin plate chromatography to determine the degree of CNSL contamination of the kernels and found this to vary between 9 to 11 ppm as long as the plant was kept clean. It could rise to 35 ppm if the cone of the decorticator was not changed and cleaned every four hours (this takes five minutes). Contamination rate also rose considerably if the nuts were not correctly roasted. In the event the roaster was extremely easy to control and we soon found that we could establish plant equilibrium conditions in 25 minutes from start up. While operating in the United Kingdom we used the grader (plate 7) to grade our cashew nuts into under 13mm, 13 - 15mm, 15 - 17mm, 17 - 19mm, or above 19mm girth. At this time we considered it necessary to always roast particular sizes, particularly as we were carrying out experimental work on the equipment. With this arrangement and by setting up established soaking and humidifying procedures we were able to obtain much whiter kernels than before and our percentage of whole kernels was approximately 79% at the discharge of the air elutriator. We used some 9,100 kgs of cashew nuts during this period and carried out seven runs of three hours or more to get a better appreciation of the way in which the machinery would react under production conditions. In general, however, we had to carry out short runs of one hour or less (average batch 90 kgs), and this caused some difficulty in that we had quite lengthy heating up, and cooling cycles to which the CNSL was subjected, but we only made a relatively small amount of new product because of the small quantity of nuts processed, because of this we found that we were roasting very badly, although the cashew nut shell liquid was apparently at the correct temperature. A check of the viscosity of the CNSL showed that it had increased from .230 N /m^2 to .710 N /m^2. The oil was changed and the roast carried out perfectly well. Table 1 gives an indication of soaking and humidification and roasting times, shell and kernel moisture content obtained and condition of kernels during the Culham trials.

PLATE 7: Raw cashew nut grader in TPI laboratories.

Table 1: Typical results from final experimental trials carried out at Culham in 1968 (1)

Weight of Raw Nuts Processed	Soaking and Humidifying Times	Moisture Content after Humidifying		Moisture Content after Roasting		% Whole Kernel (2)	Roasting Temp
		Shell	Kernel	Shell	Kernel		
1100 kgs	5 minute soak and 25 hour humidifying	12.9%	10.9%	5.6%	8.2%	74.4%	180/185°C
1018 kgs	10 minute soak 12 hour humidifying and 3 minute soak and further 12 hour humidify	11.8%	9.6%	6.7%	7.1%	73.6%	180/185°C
907 kgs	10 minute soak 12 hour humidify and 3 minute soak and further 12 hour humidify	9.8%	8.7%	4.5%	6.3%	74.0%	180/185°C
2240 kgs	10 minute soak 12 hour humidify and 3 minute soak and further 12 hour humidify	11.8%	9.2%	5.2%	6.9%	73.0%	180/185°C
68 kgs	5 minute soak 24 hour humidify and 5 minute soak and further 17½ hour humidifying	14.8%	10.8%	5.9%	8.5%	81.0%	180/185°C
1138 kgs	5 minute soak 8 hour humidify and 5 minute soak and further 40 hour humidify	14.3%	11.9%	4.6%	7.9%	78.0%	180/185°C

(1) Using Kenyan Cashew Nuts
(2) Percentage of all kernels produced

It should perhaps have been mentioned earlier in this paper that we used Dean and Stark apparatus to determine the moisture content of the shell (heating the shell in toluene and condensing and separating the vapour so produced). The oven drying method of moisture determination was used for the kernels, first cutting them up to pieces of approximately ½mm x ½mm, or to obtain a quick result the infra tester was used on kernels. In this method the small pieces of kernel of 4.5 gms weight are placed on a small scale and are heated by an infra red lamp above. When the moisture is driven off, after about 30 minutes, the moisture content can be read off as a percentage, from a scale adjacent to the pan.

To obtain a reasonably accurate impression of the efficiency of our plant we found it essential to determine the quality of the nuts with which we had been provided. We took snatch samples of 20 nuts at a time from the conveyor after the cleaner, weighed them, opened them up and found the percentage of empty bad nuts. We found that this varied from 8.2% to 19.7% bad nuts, and this obviously has a very big effect on the apparent efficiency of the plant in regard to total outturn and whole kernel efficiency.

While the UK trials were in progress, arrangements were finalised with the Government of Kenya to ship the plant to Kilifi. We had completed our work by April 1969 and had the plant at Kenya Cashews Ltd by June 1969 (see plate 8). All of the equipment was installed and tested within two weeks, and we then began a series of training runs to familiarise the African staff with the operational techniques required. We had decided that a man with natural mechanical ability should be selected to control the roaster in the first instance and that his duties would afterwards be extended to cover the whole of the process. When properly trained it would be his job to start up the plant and control roaster temperature and times, in conjunction with kernel quality. He would not control the staff, but would be known as the Process Supervisor. The operators would be controlled by a working chargehand or Staff Supervisor, who would move the men and control them to the instruction of the Process Supervisor. It was also agreed that soaking and humidifying would be controlled as a separate operation in the early stages of plant running. In the event this system worked extremely well and in two weeks the African staff were running the plant properly, and in four

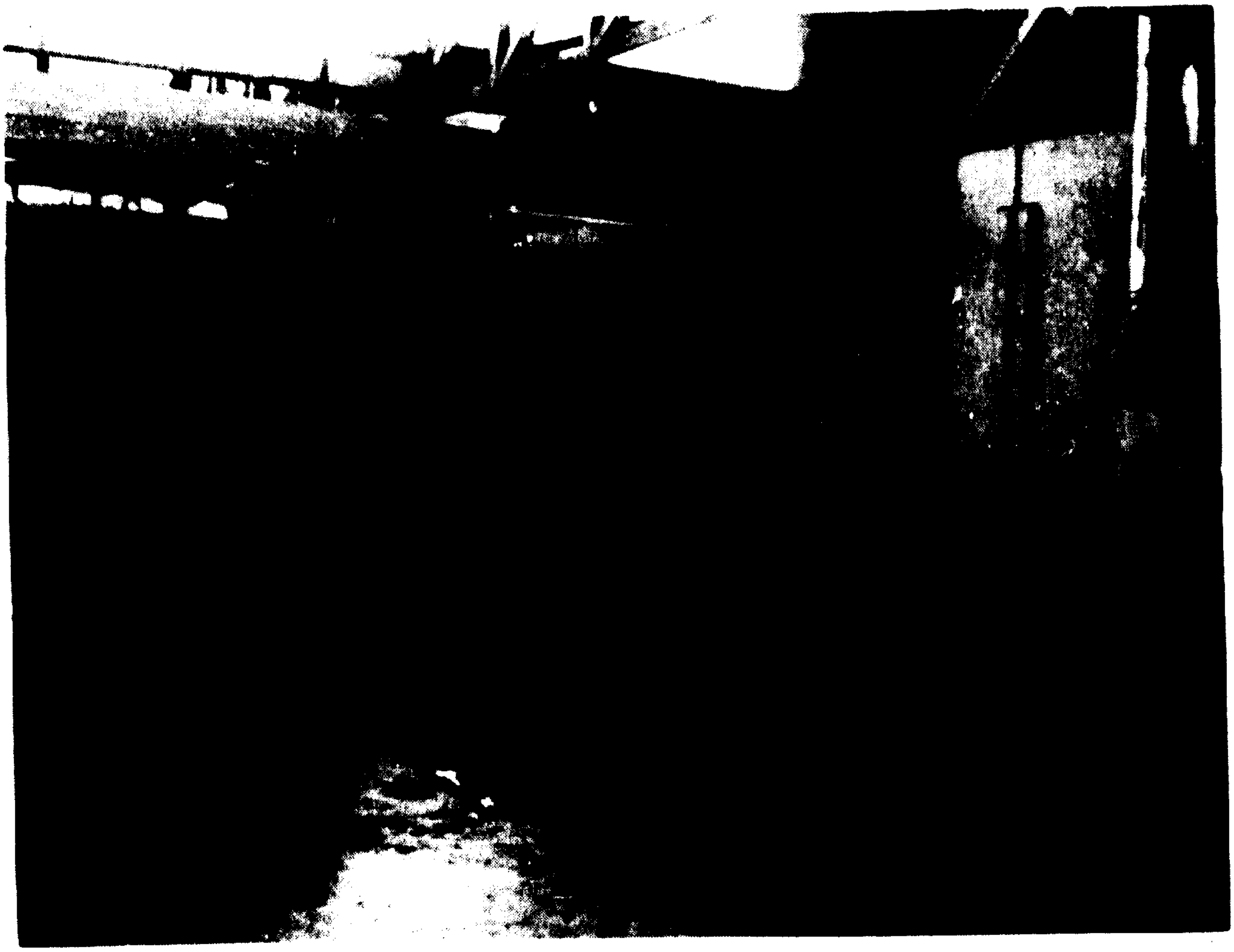


PLATE 8: Roaster, cleaner and decorticator installed in Kenya.

weeks the Process Supervisor was controlling the whole plant, but still of course under TPI overall supervision. It was not long before we could actually leave the plant to be run, and our presence was not essential: this of course was the goal which we had hoped to achieve (See plate 9). During this period we carried out a large number of experimental runs, varying moisture contents of the nuts, roasting times and temperatures, and checking the whole kernel efficiency and outturn. Table 2 gives some idea in regard to the results which were obtained.

Table 2: Typical Results from Experimental Trials carried out at Kilifi in 1969

Weight of Raw Nuts Processed	Soaking and Humidifying Times	Moisture Content before Humidifying		Moisture Content after Humidifying		Roasting Temp	% whole kernels
		Kernel	Shell	Kernel	Shell		
1910 kilos	8 minute soak and 24 hours humidifying	8.6%	8.7%	9.9%	11.7%	180/185°C	70.2%
2180 kilos	4 minute soak and 24 hours humidifying	7.9%	8.0%	9.3%	10.7%	180/185°C	71.1%
810 kilos	6 minute soak and 24 hours humidifying	7.6%	7.8%	9.4%	11.2%	180/185°C	71.0%
1910 kilos	8 minute soak and 24 hours humidifying	7.7%	8.2%	10.1%	12.7%	180/185°C	75.1%
1910 kilos	8 minute soak and 24 hours humidifying	8.4%	8.8%	10.0%	12.0%	180/185°C	74.3%
1910 kilos	8 minute soak and 24 hours humidifying	9.7%	8.5%	9.7%	10.9%	180/185°C	78.2

We found that with the nuts in their condition at that time of 8.5% mc. shell and 8.0% mc. kernel, a soaking time of eight minutes, with humidifying time of 24 hours, followed by roasting for 1.5 minutes at 180°C gave the best results. In these early

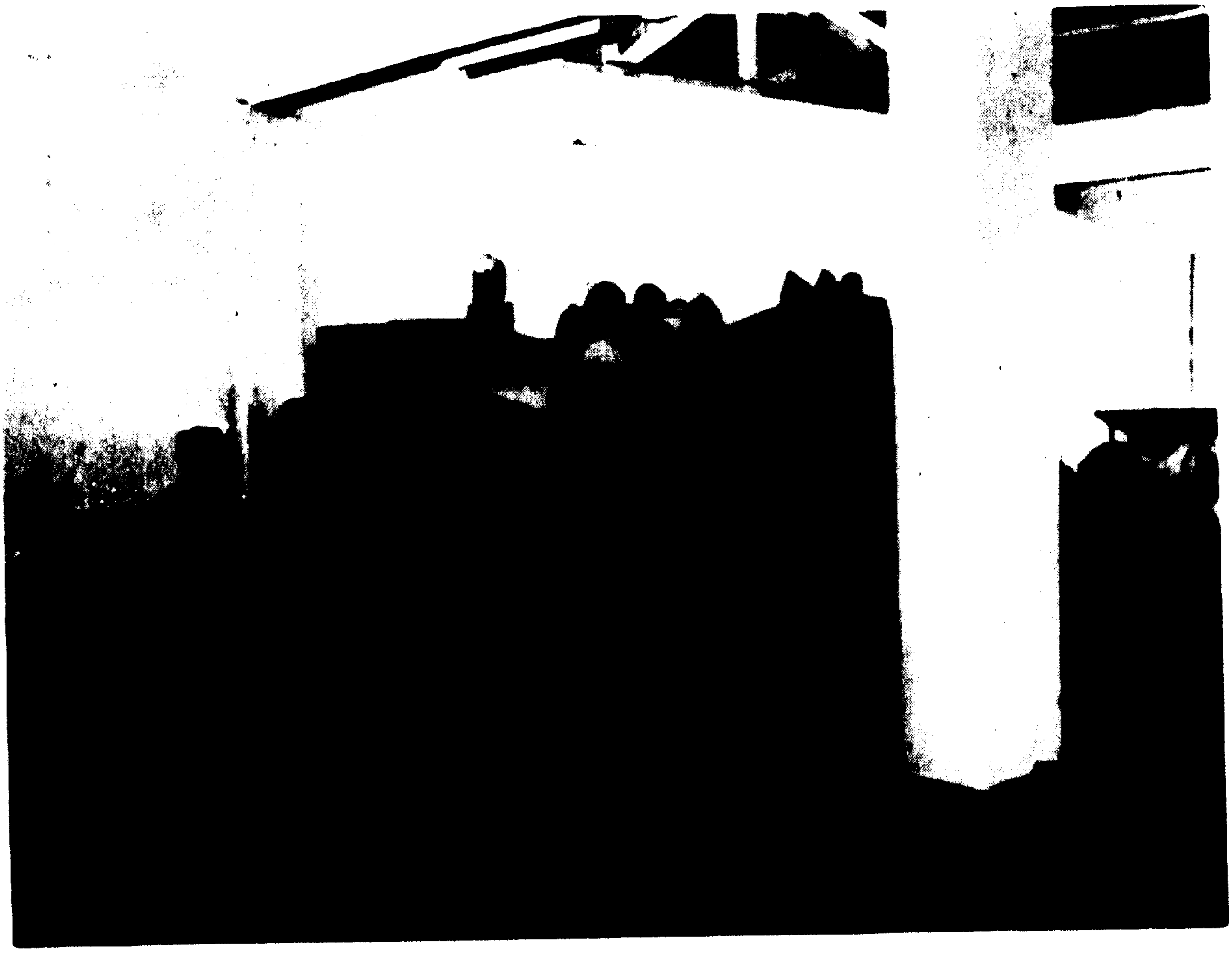


PLATE 9: Cashew plant being operated by African staff in Kenya.

days we had some difficulty in obtaining the actual outturn figures, because the kernels from the TPI plant and from Kenya Cashews Ltd were peeled by the same team of operatives, and a certain amount of confusion resulted from this. Indeed, it was not until we went back to Kilifi for the second time and after the plant had been running for 14 months that we managed to get a complete picture of the outturn of the plant. Table 3 shows the results we obtained during the final weeks of plant operation in Kenya before we returned to the United Kingdom. By this time it had been clearly established that the kernels were white and of extremely good quality, furthermore the number of scorched kernels was small and lower than the proportion obtained in the conventional processing.

Table 3: Typical results from final Experimental Runs carried out at Kilifi in 1970
(Kernel count after decortication and before drying, peeling and grading takes place)

Weight of Raw Nuts Processed kgs	Soaking and Humidifying Times*	Moisture Content before Humidifying		Moisture Content after Humidifying		Roasting Temp	% Whole Kernels
		Shell	Kernel	Shell	Kernel		
1090 kgs	NIL	8.8%	8.2%			180/185°C	83%
1090 kgs	NIL	9.4%	9.0%			180/185°C	83%
1360 kgs	NIL	10.0%	9.5%			180/185°C	82%
1090 kgs	NIL	9.2%	8.7%			180/185°C	81%
476 kgs	NIL	9.2%	8.4%			180/185°C	82%
1090 kgs	NIL	9.4%	8.5%			180/185°C	81%

* As these nuts had been in store less than 3 months and the raw moisture contents were fairly high they were not soaked and humidified

We could now turn to the necessary exploratory work on cashew shell firing for the roaster. We checked the calorific value of shell from Kilifi and found that it was 2040 x 10^3 Joules/kg and this of course meant that it was quite a high quality fuel. A small fire box .61 metres cubed was constructed of mild steel and fitted with a fire grate, a blower was provided to pass air through the fire bed, and thermo-couples were provided to measure the temperature obtained. This piece of equipment was set up out of doors and no stack was provided - the gaseous products of combustion were allowed to discharge straight out of the back of the fire box at the top. We found that we obtained temperatures in excess of 750°C at the exhaust gas outlet from the firebox, and that the quantity of ash which remained after combustion was extremely small. Our pilot plant fire box was made of mild steel and lined with refractory brick - and the duct was made of mild steel with no lining. We made this prototype to see that the method we had in mind would give temperature differentials across the roaster heating tubes which were similar to those obtained in the Kilifi plant.

A mechanical stoker capable of feeding from 9.0 kg to 61 kg of cashew shell per hour, with an air blower attached was fitted to the fire box and a damper was provided to limit the amount of combustion air as necessary. We had thought that it might be necessary to fit orifice plates over some of the tubes nearer to the fire box, but found that this was not required. Even in its first form this system worked extremely well and that we were able to obtain a very straight line from the temperature recorder chart, when we were controlling a roast at 180°C, or 185°C. Work was immediately started on a cashew firing system suitable for Kilifi and we decided that both fire box and duct should be angle framed and made of refractory fire bricks. This unit was manufactured by December 1969 and was given trials at Culham. These proved quite successful and we found that it was even easier to control the roasting temperature using the cashew firing device than it had been when we had gas heating. A series of test runs showed the following times for raising temperature and rate of fuel useage, both while temperature was being reached and when the plant was actually processing. The average amount of fuel used during "light up" was 77 kg/hr and the amount of fuel used during a roast was 38 kg/hr. This indicated that during an eight hour process run with a two hour light up period we should use 154 kgs of fuel for light up and 304 kgs of fuel while running, a total of 458 kgs. We would normally expect to produce 130 kgs of shell per hour or 1240 kgs of shell during an eight hour run and would, therefore, use only 37% of our total shell produced for roasting. It followed that we should have 75 kgs per hour to use for other purposes, such as drying the cashew kernels preparatory to peeling.

The cashew shell firing equipment was shipped to Kilifi in April 1970 and took five days to instal. We found during the first long trial runs that insufficient allowance had been made for the very considerable thermal coefficient of expansion of the refractory. Modifications were, therefore, made to the duct at the point of entry into the fire box (see plate 10 and 11). These proved quite successful and control was certainly as easy as at Culham. The African operators very rapidly learned to light up and control the roaster using this method, and preferred it to the original gas firing system. Table 4 indicates the shell made and shell used during a series of runs, and I have also indicated the weight of kernels, percentage of all wholes, percentage of white wholes and total outturn during each run.

Table 4: Typical Results of Shell made and used during Experimental Runs carried out at Kilifi 1970
(Kernel count after decortication and before drying, peeling and grading takes place)

Weight of Raw Nuts Processed kgs	Shell made kgs	Shell used kgs	Shell used during temperature raising kgs	Overall Hourly rate of shell useage kgs	Roasting Temp	% Wholes
1090 kgs	502	313	159	45	180/185°C	81%
1090 kgs	462	361	170	57	180/185°C	83%
1090 kgs	460	376	148	54	180/185°C	83%
1360 kgs	600	371	155	56	180/185°C	82%
1090 kgs	494	346	169	60	180/185°C	81%
1090 kgs	505	367	164	58	180/185°C	79%

These results are after 4 hour duration trials. See text above for results from 8 hour trials.

PLATES 10 and 11:

Table 5 indicates the results of grading a typical four hour output from the TPI plant at KC Ltd.

Table 5: Typical Grading results from Experimental Runs carried out at Kilifi 1970
(Kernel count immediately prior to canning)

Weight of Raw Nuts Processed	% all wholes	% white wholes	% Butts*	% Pieces	% Splits	% Small Pieces	% Local Quality Kernels	Graded kernels as percentage of Raw Nut Weight
543 kgs	59.1%	47.4%	7.5%	9.0%	2.0%	19.0%	1.5%	23.5%
1090 kgs	54.5%	47.2%	8.0%	10.5%	1.5%	21.0%	1.5%	23.5%
1090 kgs	56.5%	49.4%	7.0%	10.0%	1.0%	21.0%	1.5%	24.4%
1360 kgs	53.2%	49.4%	9.0%	10.0%	1.5%	23.0%	1.0%	23.7%
1090 kgs	51.3%	45.0%	9.3%	12.0%	2.3%	20.7%	1.4%	24.0%
1090 kgs	56.7%	50.4%	7.0%	11.0%	2.0%	18.0%	2.0%	23.2%

* Difference between 100% and the percentages above when totalled is caused by bad nuts.

The kernels, after leaving the plant with approximately 50% of the testa removed during the decortication process are put in baskets each holding 4.05 kgs of kernels and are dried from about 6.3% mc. down to 3.9% mc. in a paraffin heated drier. These are dried at 70°C for 6 hours and then the drier is shut down. The kernels are removed after 8 hours and are then peeled by hand, graded and sealed in tins, each tin holding 10.1 kg of kernels.

The hand peelers find the testa from the TPI roasted kernels much easier to remove, after drying, than the kernels which have been processed in the normal way by KC Ltd.

Following the successful trial period of two years in Kenya arrangements were made for the Sturtevant Engineering Company Ltd, Hamlyn House, Highgate Hill, London N19 to manufacture the plant under licence. The writer assisted in the commissioning of the first two units at the factory of Socoor Tavares in Lourenco Marques.

The results obtained were very similar to those from the units at Culham and

Kilifi. It was found possible to produce 80% of whole kernels after decortication, if the raw nut feed was limited to 216 Kgs/Hour, with the feed increased to 272 Kgs/Hour the whole kernels dropped to 70 - 73%. (See Table 6 below). The degree of CNSL contamination of the kernels after peeling was 11.9 ppm using the thin plate chromatograph method.

Table 6: Typical Results of Experimental Runs carried out at Lourenco Marques 1971
(These results are from commissioning trials and should improve further when production runs start)

Weight of Raw Nuts Processed in Kgs	Hourly Feed Rate in kgs	% Whole Kernels	Soaking and Humidifying Times	Moisture Content before Humidifying		Moisture Content after Humidifying	
				Shell	Kernel	Shell	Kernel
2210 kgs	276	72.7%	1 hour spray 2 hour humidify + 1 hour spray 2 hour humidify + 1 hour spray 48 hour humidify	8.0%	6.0%	15.1%	12.0%
2150 kgs	240	74.2%	1 hour spray 2 hour humidify + 1 hour spray 2 hour humidify + 1 hour spray 48 hour humidify	13.5%	8.0%	17.1%	9.0%
2150 kgs	227	75.1%	1 hour spray 2 hour humidify + 1 hour spray 2 hour humidify + 1 hour spray 48 hour humidify	8.0%	6.0%	14.4%	12.0%
408 kgs	240	82.1%	1 hour spray 2 hour humidify + 1 hour spray 2 hour humidify + 1 hour spray 48 hour humidify			15.7%	9.0%

One very interesting point emerged during these trials. It was found that there is a considerable difference between the soaking and roasting characteristics of the Kenyan and the Mozambique cashew nuts. To produce the maximum quantity of whole white kernels after decortication, it was found that it was necessary to precondition the raw nuts to give a shell moisture content of 14% to 16% and a kernel moisture content of 9% to 12% before roasting. The soaking and humidifying techniques used for Kenyan nuts were not appropriate. The method which proved satisfactory and which was adopted was to spray the nuts for one hour, leave for 2 hours then spray again for one hour. With three sprayings of this type followed by a 40 hour humidification period the moisture content of the kernels could be increased from 7% to the 10% required. With these increased moisture contents it was necessary to roast at 195°C instead of the 180 - 185°C roasting temperatures used in Kilifi.

Advantages of the TPI/Sturtevant plant

1 Only one supervisor and 8 men required to operate a 500,000 Kg per year unit.

2 Low capital cost.

3 Units can either be used individually in a village or co-operative, or collectively in a factory.

5 Operation is easy to learn and to carry out.

6 No fuel for roasting (or drying) is required and running costs are therefore low.

7 The plant takes up a small amount of space per unit, and building costs are kept down.

8 Although more sophisticated decortication systems can obtain a higher percentage of whole kernels after decortication, the breakage rate during peeling is considerably higher than with the plant under discussion. This is because the gentler method of removing the kernel in the former process produces a large number of apparently whole kernels, already separated at the cotyledon, and these become splits when the testa is removed. These kernels would appear as splits after decortication, with the TPI plant, and by using the correct preconditioning and roasting technique up to 60% of whole kernels may be available for canning.

9 The roasting system is very easily and accurately controlled and by using correctly preconditioned nuts can produce 94% unscorched kernels.

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The writer wishes to thank his colleagues at TPI for their part in the work needed to produce the cashew processing plant.

Mr.M.J.D. Down, Chief Executive, and the design and manufacturing staff of Sturtevant Engineering Ltd, Hamlyn House, Highgate Hill, London E19 are also thanked for the part which they have played in the design and manufacture of the production model.

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SUMMARY

EXPERIMENTAL WORK AND OVERSEAS TRIALS OF A CASHEW NUT PROCESSING PLANT DESIGNED AND BUILT BY THE TROPICAL PRODUCTS INSTITUTE [1/]

by

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The cashew nut has a spongy shell enclosing a kernel covered in testa or peel. The shell contains cashew nut shell liquid (20-25 per cent by weight) which is toxic and can be polymerized by heating. It has been established that one method of removing the shell, and keeping kernel damage to a minimum, is to roast the nut until the relatively soft shell becomes crisp; three or four taps from a piece of wood, delivered on the plane of cleavage of the nut, will then release the kernel.

The increasing demand for cashew nut kernels by the more sophisticated countries has brought a demand for mechanization, and some quite complex and expensive decortication plants have been produced. With a view toward encouraging village development, the Tropical Products Institute was asked, six years ago, to develop a small, inexpensive and simple decortication unit.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This paper has beenrreproduced without formal editing.

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After review of many possible methods we decided that it would be best to use a centrifugal decorticator in which a rotating disc, fitted with vanes, threw the roasted nuts against target plates arranged round the periphery of the cracker. Impact velocity was found to be 19.6 m/sec. for a six gram nut. The report describes the cracking unit, gives dimensions, a sketch and some photographs. A great deal of time was spent investigating the soaking and humidification times required to give a crisp shell and a rubbery kernel when the nut was roasted in cashew nut shell liquid at 180-185°C, and it was found that a kernel m.c. of 8-10 per cent and shell m.c. of 10-12 per cent gave the desired results with Kenyan nuts.

The first complete pilot plant consisted of a grading machine, then a soaking and humidifying process for the raw nuts, followed by a gas-fired roaster (afterwards modified to use cashew nut shell as fuel). The nuts were roasted at 180-185°C and then passed through a rotary cleaner where they were cooled and tumbled with sawdust. Cleaned and roasted nuts were passed by conveyor to the top of the centrifugal cracker and were then impacted against the target plates. A mixture of shell, kernels and uncracked nuts then passed by conveyor to a reciprocating screen, the whole nuts passing over the screen, and joining the new feed to be recycled through the cracker, while the shell and kernel passed through the screen and were separated by means of an air elutriator. This equipment is described in some detail in the report.

The pilot plant described above was given trials at the TPI laboratories at Culham (UK), and we found that we were able to obtain 73-81 per cent whole kernels after decortication. The roaster worked well, was easily controllable, and only 6-10 per cent of the kernels were scorched. During these trials we used the oven drying method to determine the kernel moisture content and Dean and Stark apparatus for the determination of the moisture content of the shell.

Following the trials in the United Kingdom, the plant was shipped to Kenya for work under field conditions. The machine took two weeks to install in a factory at Kilifi and the African staff could run the plant in two weeks. The way in which the supervisors were selected is described in the report. We obtained between 81 per cent and 83 per cent of whole kernels during our final experimental runs; the kernels were white, of good quality and with little scorching.

After the machines had been run by the factory operatives for a few months we added a cashew shell firing device to the roaster. This consisted of a fire box fed with cashew shell by means of a mechanical stoker with forced draught. The hot gaseous products of combustion passed through a duct from the firebox through the 24 transverse heating tubes in the roaster and via a stack to the atmosphere. We gave this equipment trials in the United Kingdom before shipping it to Kenya. The trials in England and in Kenya were very satisfactory and the African operatives found this roaster easier to control than when it was gas-fired.

The grading results from the Kenyan kernels showed that from 51.3 to 59.1 per cent whole kernels were canned, and this was considered to be very satisfactory. Peeling of the product after drying down to 3.9 per cent m.c. was found to be slightly easier than the kernels which were produced by hand cracking.

The successful trials in Kenya were followed by trials of two production plants in Lourenço Marques, Mozambique. The machinery was manufactured by Messrs. Sturtevant Engineering Co. Ltd. (UK) and very satisfactory results were obtained. Whole kernels produced ranged from 73 to 80 per cent of the total produce from the decorticator, depending on the rate of raw nut throughput. It was noted that different soaking and humidifying techniques were required for Mozambique as opposed to cashew grown in Kenya.

Having described the work carried out to date, the report is concluded by listing the advantages of the TPI/Sturtevant plant.

* * * * *

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