



PLATE 1.—"Basket-box" method of fermentation—beans being transferred from one basket to another.

PROCESSING METHODS FOR CACAO GROWERS IN PAPUA AND NEW GUINEA

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In this article, Mr. Bridgland discusses cacao processing from the point of view of the individual cacao grower. He tells how to organize picking, and describes different methods of processing and the stages involved. Mr. Bridgland also describes several variations of a new method of processing beans to give an improved and consistent product and goes into the organization and construction of a fermentary to handle the work.

THE soils and climate in the cacao-growing areas of Papua and New Guinea, in conjunction with the hybrid "Trinitario" type which is grown, contribute to the considerably higher average yield obtained in New Guinea as compared with overseas cacao-producing countries. These same factors, however, are associated with the greater difficulty in processing in a way which guarantees good and uniform development of chocolate flavour.

The object of work on this subject at Keravat has been to devise reliable methods of processing which regularly ensure the production of high-quality beans. Information obtained as a result of work, both here and overseas, on the principles involved in fermentation and drying is contained in the preceding article. This paper will summarize the application of this information and the recommendations of the Department of Agriculture, Stock and Fisheries.

FIELD OPERATIONS

Plantation field operations, which involve harvesting, gathering, breaking and transport of the wet beans to the fermentary, should remain the same no matter which method of processing is used. All field operations should be completed in four or five days.

Harvest (Day 1)

Complete the harvest for a given batch in a single day. All beans will then be in a uniform state at the commencement of fermentation. The practice of harvesting small quantities over a period of a week and then fermenting them together is unsatisfactory.

All trees should be harvested at three- or, at the very most, four-weekly intervals. During the flush-crop it is frequently necessary to harvest all trees weekly to keep pace with the crop. If the interval between harvests is prolonged, losses through disease and germination within the pod will be severe. Records at Keravat (Van Velsen, unpublished) show conclusively that losses from "Black Pod" increase from an average of about 5 per cent. to about 15 per cent. if the interval between harvests is prolonged from three to five weeks. Such losses cannot be ignored.



PLATE 2.—Pods should be cut cleanly, with sharp harvesting hooks.

During actual harvesting, hooks should be kept razor sharp so that pod-stalks are cut cleanly and not torn away from the branch. Only fully-ripe pods should be harvested. Maturity of pods is indicated by colour changes. These

changes are variable in the hybrid type of cacao grown in Papua and New Guinea. Common colour changes are from green (immature) to yellow (mature), dull red to bright red and red/green to orange/yellow. With a little experience, labourers have no difficulty in recognizing mature pods. A slight green colouration around the very butt of the pod is not an indication of immaturity. The type of pod and its colour have no significance during fermentation.

At all harvests, sufficient trees should be picked to ensure a yield of enough beans to give a minimum depth of 15 inches or a maximum depth of 2 feet 9 inches of beans in a number of fermenting boxes.

In the course of all harvests, diseased pods must be removed from the trees. The question is often raised as to whether these diseased pods should be left on the ground under the trees or removed. The two main organisms to be considered are *Phytophthora palmivora* (black pod) and *Botryodiplodia theobromae* (brown pod). In the former case, the spores are carried about by "splash" only. There is some evidence that diseased pods lying on the ground can infect pods or flowering cushions within about two feet of ground level. A "black pod" hanging near the top of the tree could, of course, infect a large part of the tree. The spores of *Botryodiplodia* are wind-borne, but the organism does not produce spores immediately on the newly-rotting pods as does *Phytophthora*. Spores are produced only when the pods are well-rotted and even then they do not have the same ability to penetrate undamaged pods as do those of *Phytophthora*. Until more is known about the subject, present experience indicates that the safest course is to remove diseased pods from the plantation; but failure to do this would not be expected to lead to outbreaks of epidemic proportions.

Because of the skill and reliability required for efficient harvesting, it will pay the grower to hand-pick his harvesting gang and use it consistently.

Gather-Heap (Days 2, 3 or 4)

There is no necessity to "gather" as the pods are harvested, but there is no objection to this. The manager should mark out convenient "breaking" points, so that long cartage of pods is avoided and pod-skin disposal facilitated. Heap the pods at these points. Heaping should be completed by the end of Day 3 or Day 4.

Break-Cart (Day 4 or 5)

There should be an interval of three or four days between harvesting and breaking. A shorter interval should be avoided. An interval longer than four days will often cause serious losses through pod diseases and germination of beans within the pod. It may also interfere with fermentation.

Discard any diseased pods in which the pulp is visibly affected and any pods in which the beans have germinated. Pods should be broken with short, heavy sticks rather than knives, as there is a risk of cutting and damaging the beans. It is usually better to divide the labour between those cracking the pods and those extracting the beans and placenta or pith, which is discarded.



PLATE 3.—Pods being broken into special baskets on plantation.

The pods should be broken into boxes or baskets which can be kept reasonably clean. The practice of breaking into foul-smelling, mouldy bags is both inconvenient and detrimental to fermentation. Do not allow beans to become affected by rain during breaking and cartage.

For the most part, the spread of disease does not enter into the question of pod-skin disposal, except, as noted above, that high heaps of rotting skins could increase the rate of "black pod" infection. It is recommended that pod skins be spread around the plantation whenever it is economic to do so. With tropical soils, any form of mulching will be valuable. Skins rapidly decay if left on the surface of the soil and most of the useful elements released by this decay will be leached into the soil. If pod skins are buried, they resist decay and there is no particular virtue in this procedure.

On plantations which are well served with roads, it may be possible to shift breaking points regularly and this avoids any problem of excessive accumulation. Where this cannot be done and where skins cannot be redistributed, they should be thrown into natural depressions, gullies or creeks. This will prevent the accumulation of high heaps of skins. The economics of dispersal of skins will largely depend on soil fertility. On marginal soils, the order of benefit from this practice will be much higher than on the very fertile soils.

The question is sometimes asked whether the spreading of pod skins is likely to encourage or spread the root-rotting fungi. Generally speaking, the spread by spores of the diseases which occur in New Guinea is very limited, especially if diseased trees are dug out and burnt as soon as infection becomes evident. If this is done, the organisms will generally have insufficient time to release spores. Pod skins are most unlikely to become infected from this source before they decay and there is no risk at all once the tissue is dead. The root-attacking fungi which concern the cacao planter usually spread by rhizomorphs or threads growing along living roots in the soil. Heaps of pod skins could become infected only if there were a soil infection to begin with. If this were so, cacao trees would in all probability become infected sooner or later, whether there were pod skins about or not.

METHODS OF FERMENTATION

Existing Methods

Present methods of fermentation in Papua and New Guinea vary considerably but for convenience in description they are lumped under the term "Old Technique". In its most common form, this consists of placing the wet beans in wooden sweat-boxes, usually 5 feet long by 4

feet wide by 3 feet deep. Fermentation proceeds for six and three-quarter to eight and three-quarter days (usually seven and three-quarter days) with daily or alternate daily turning, according to the particular plantation and the time of the year.

The results of this method are variable. They are sometimes good and sometimes poor, but are usually irregular in respect of apparent quality as judged by the "cutting test" and of real quality as judged by the flavour of chocolate made up from the beans. Chocolate flavour varies from complete absence to good strength. Side-flavours such as liquorice, caramel or raisin, which frequently but not invariably accompany weak chocolate flavour, are usually pronounced. Excessive acidity frequently constitutes a serious defect.

Objections to "Old Technique"

The irregular flavour development noted above can be traced to variation in temperature and acidity during fermentation. These factors may not be brought to the optimum conditions required for the development of the precursors of chocolate flavour, or these conditions may be developed only very slowly during fermentation, necessitating prolonged fermentation. Long ferments are also made necessary by the wide variation in the conditions within the sweat-box. To produce beans which have the appearance of being well-fermented, processing must be continued for so long that flavour is frequently lost by over-oxidation.

Variation in the pattern of fermentation using the "Old Technique" largely reflects variation in the pulp at the start of fermentation. This pulp variation is pronounced in the Gazelle Peninsula of New Britain. "Dead Ferments" (those in which temperature fails to rise or rises only very slowly to a sub-optimal level) cannot be avoided. These frequently lead to even longer fermentation and putrefaction. Beans resulting from this treatment sometimes develop the appearance of being well-fermented, but may completely lack chocolate flavour and may possess a variety of defective flavours.

If, in any part of the Territory, results from the "Old Technique" are not consistently good, growers are advised to scrap the method in its present form. For those who feel that they must retain it, the following points should be noted:—

(1) Daily turning usually results in better temperature development and slightly lowered acidity, as compared with alternate daily turning.

(2) The bottoms of the boxes used for the first three days of fermentation should be drilled with half-inch holes on a two-inch-square pattern. For boxes used for the remainder of fermentation, drill holes only on a six-inch-square pattern.

(3) Better results will be obtained if sweat-boxes are not filled to a greater depth than 2 feet 6 inches.

(4) A fixed duration for fermentation cannot be set. The grower should be guided largely by the odour of the beans. When the vinegary odour diminishes and when signs of putrefaction begin to develop in the corners, on the sides and bottoms of the fermenting boxes, turn the beans out to dry. On no account should fermentation be continued. Fermentation should never last longer than eight days.

METHOD "A"—"Modified Old Technique"

This method involves only a slight departure from the "Old Technique". Two different fermenting boxes are required. Fermentation begins in boxes 5 feet by 4 feet by 1 foot 6 inches deep on the fourth day after harvesting (i.e., on Day 5). The beans are turned at 8 a.m. on Days 6 and 7. At 8 a.m. on Day 8 (i.e., after almost three days in the shallow boxes), the contents of two shallow fermenting boxes are turned into a larger box, 5 feet by 4 feet by 3 feet deep. Fermentation continues in this type of box for a further four days (i.e., Days 9, 10, 11 and 12) with daily turning. Thus, fermentation is completed in seven days, bringing the process within a weekly cycle. The beans are then turned out to dry.

Fermenting Boxes Lay-out and Design

The possibility suggests itself of having a single battery of the shallow fermenting boxes of greater length and breadth (say 10 feet by 4 feet by 1 foot 6 inches or 8 feet by 5 feet by 1 foot 6 inches deep) instead of the double battery of smaller dimensions (as in Diagram I). There is no objection to this, but "turning" is facilitated in the smaller boxes.

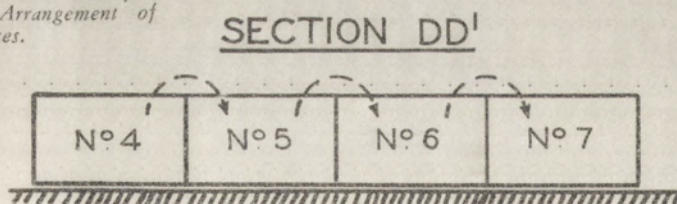
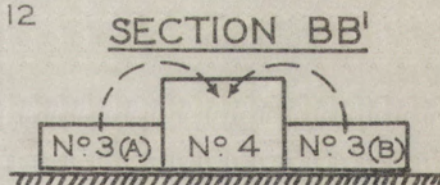
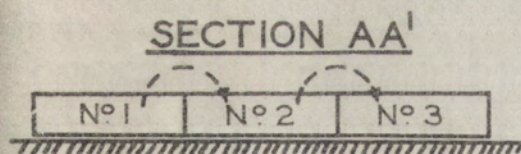
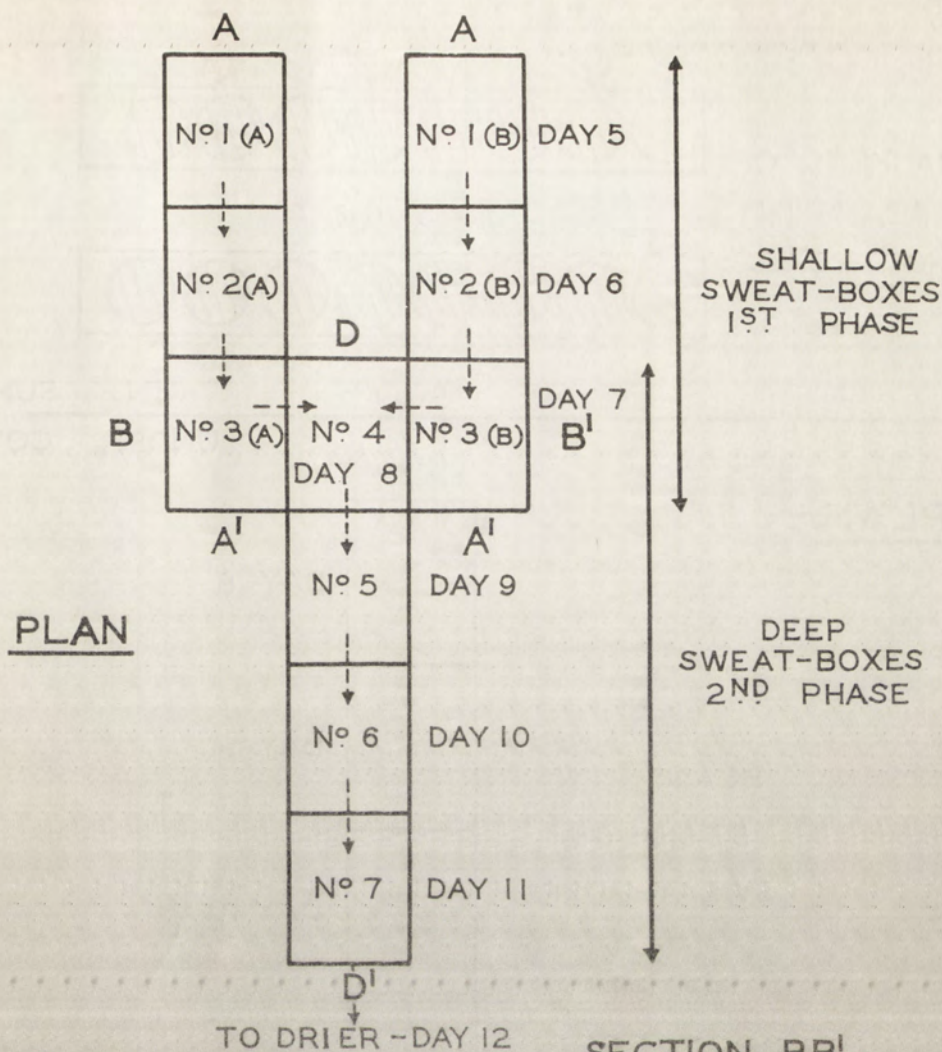


DIAGRAM I.—Method "A" Modified
"Old Technique". Arrangement of
sweat boxes.

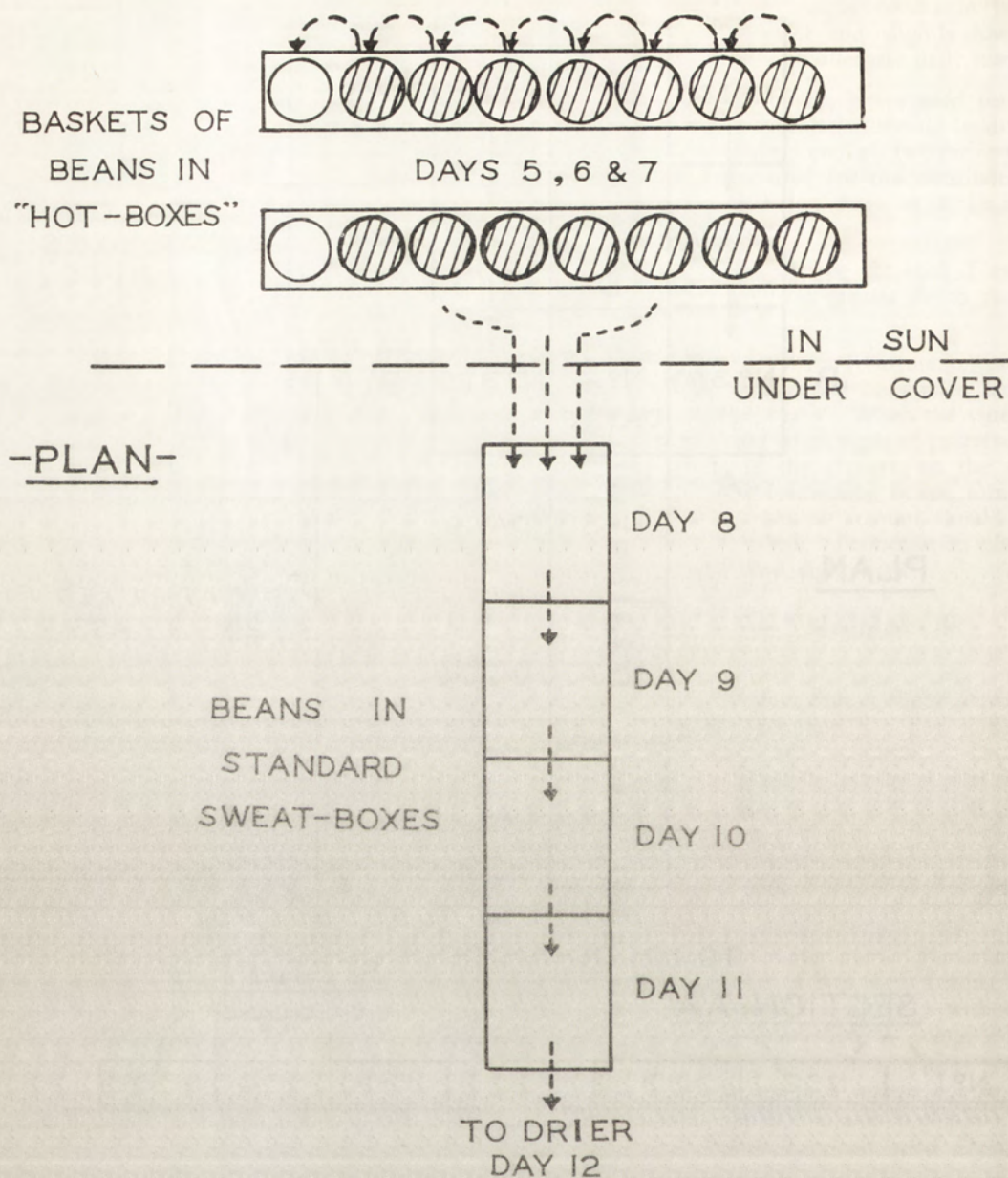


DIAGRAM II.—"Basket/Box" fermentation. Arrangement of equipment.

The sides of the shallow boxes can remain fixed. At this height there is no advantage in having the sides constructed so they can be dismantled. The sides of the shallow boxes can be made double-walled with some insulating material in the intervening space. This will conserve heat.

For the larger boxes in the deep phase of fermentation, the construction described by Henderson (1954) is recommended.

Provision for drainage of sweatings will be necessary only under the smaller sweat-boxes in the shallow phase. After this, there are no further sweatings, but provision must be made for draining away water used for washing the boxes. There **MUST** be a three-inch to four-inch air-space under all fermenting boxes. Half-inch holes should be drilled on a two-inch-square pattern in the bottoms of the shallow boxes in the first phase. Half-inch holes should be drilled on a six-inch-square pattern in the bottoms of the deep fermenting boxes in Phase 2.

Results

This method gives a sharper and more reliable temperature rise in the early stages of fermentation. Acidity develops more rapidly and reaches about the same level as in the "Old Technique". Beans are better fermented and flavour is improved. The effects of pulp variation are not as pronounced as in the "Old Technique". Slow ferments are not eliminated. The method gives a significant over-all improvement, but since a much more reliable method is available (Method "C"), it is not generally recommended.

METHOD "B"—"Basket/Box Fermentation"

This method has been developed in an attempt to find a simple, improved method suitable for use by central fermentaries in the Gazelle Peninsula, where management poses special problems, particularly for those in the cooler and wetter areas where difficulties with fermentation are marked.

The method involves fermentation in baskets placed in "hot-boxes" in the sun for three days, followed by conventional box fermentation for a further four days.

The beans are first placed in strongly-constructed cane baskets equipped with very strong

and well-constructed carrying handles. The baskets are 20 inches high, have a top inside diameter of 24 inches and a bottom diameter of 16 inches. The bottom of the basket is not flat, but is slightly "coned" upwards in the centre. Each basket will hold about 200 lb. wet beans, or just under four cubic feet.

Baskets are placed in "hot-boxes" in batteries of eight, seven baskets being filled with beans and the eighth basket remaining empty to permit "turning". The "hot-box" is constructed of light timber and corrugated, galvanized iron. The outside of the box is painted black and the inside white. To accommodate eight baskets the hot-box should be 19 feet long and 2 feet 6 inches wide and the rims of the baskets should be flush with the top of the sides of the box when the lid is removed. A pole can then be run through the handles of the baskets and "turning" can be simply and quickly accomplished. A light lid consisting of a rectangular frame, covered with black-painted corrugated

PLATE 4.—Baskets in fermentation box with lid removed. Note black-painted side to take advantage of solar heat.



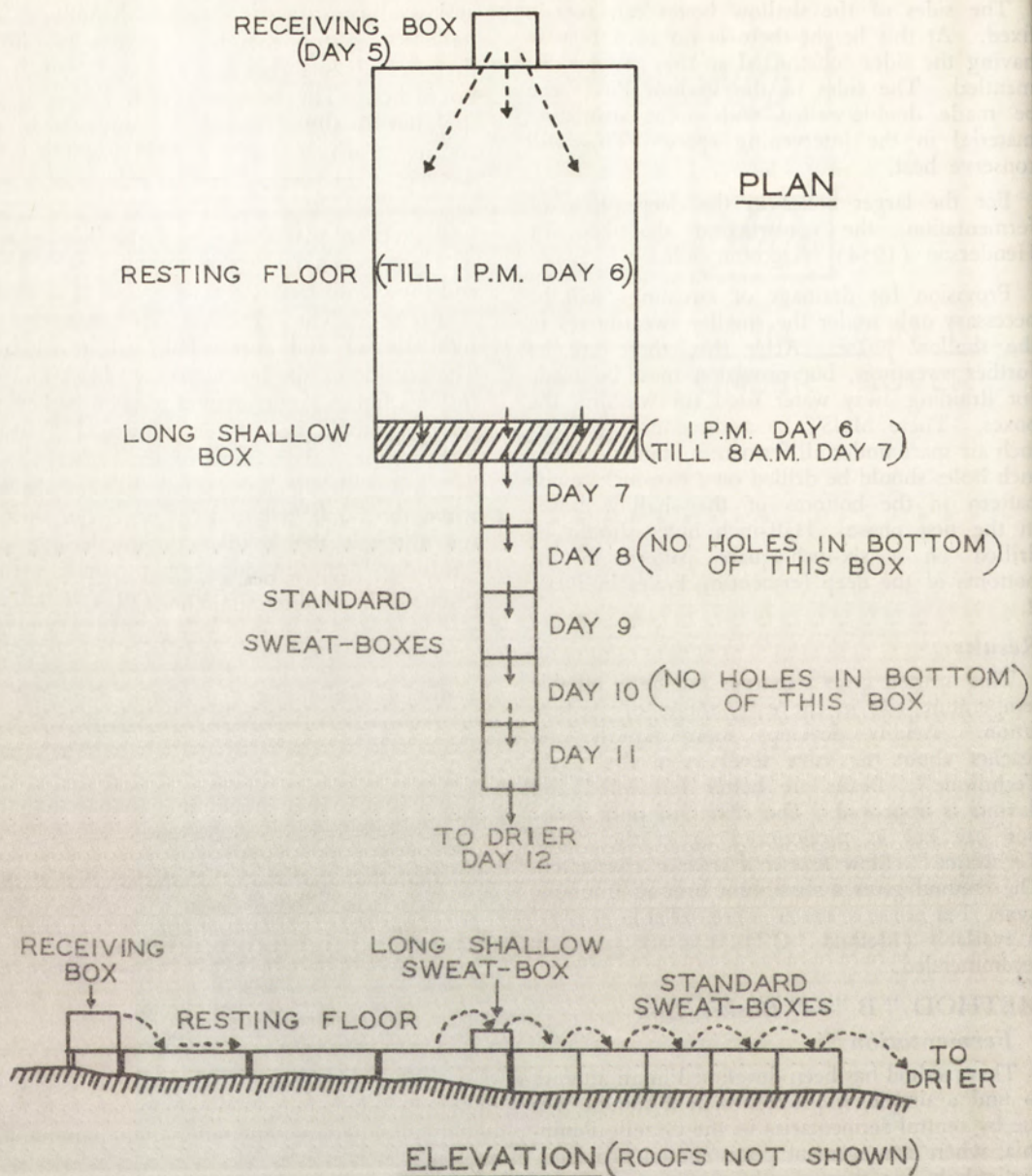


DIAGRAM III.—Method "C"—"New Technique".

iron, covers the hot-box to give a reasonably close seal. The sides of the lid must be deep enough to keep the lid clear of the handles of the baskets, which stand about five inches above the rim. The baskets stand on 3-inch by 2-inch runners placed on the ground inside the hot-box.

On arrival at the fermentary, 14 baskets (two batteries) are filled with beans. These are turned every day for three days at 8 a.m. to 9 a.m. (on Days 6 and 7). After two and a half to three days, the contents of the 14 baskets are tipped into a conventional sweat-box where fermentation proceeds for a further four days with daily turning. Thus, fermentation is completed in six and a half to seven days.

Results

The method gives rapid temperature development (more rapid than Method "A") because of the reduced volume and heat assistance from the hot-box. The assistance from solar heat is advantageous but, basically, the method does not depend on this. Acidity is developed quickly, but reaches a lower level than in the "Old Technique". Flavour development is satisfactory, but not outstanding. The method is not affected greatly by pulp variation.

The additional handling is a disadvantage, but is largely offset by the greater reliability. The method is flexible, as the times at which the beans are turned can be varied, provided they are turned each day, without greatly affecting the results. The phase in the baskets may be prolonged for a day and the period in the sweat-boxes reduced by a day without any very apparent significant effect.

The method can be recommended only under special circumstances.

METHOD "C"—"The New Technique"

This method is recommended for general use. It departs from the "Old Technique" by introducing a short "resting phase" and by fermenting in a shallow layer for 19 to 20 hours subsequent to the "resting phase". This is followed by five days' fermentation in standard sweat-boxes 5 feet by 4 feet by 3 feet deep.

As the beans arrive at the fermentary, they are placed in a "receiving" or "draining" box. The beans remain in the receiving box until 6 a.m. the next day, regardless of the time

they were received. During this period the "sweatings" drain away.

The beans are then spread out on the resting floor where they remain for six to seven hours with regular stirring. At 1 p.m. they are placed in a large and shallow fermenting box on the resting-room floor. The beans should be 12 to 15 inches deep. This box can conveniently be placed across the end of the "resting floor". The beans remain in this box for 19 to 20 hours (i.e., until 8 a.m. the next day) and are then transferred to standard fermenting boxes. Fermentation continues in these boxes for five days and the beans are turned at approximately 24-hourly intervals. Fermentation is completed in six and a half to six and three-quarter days. Fermentary lay-out for this method is given in Diagram 4.

Detailed Specifications:—

Day 1—Harvest.

Day 5—Break. Beans to receiving box, usually midday to 4 p.m. but not critical.

Receiving box to have a capacity of 60 cubic feet of wet beans, but should be loaded with 52 to 55 cubic feet only. Bottom of receiving box to be drilled in half-inch holes on a two-inch-square pattern.

Dimensions of receiving box not critical. The object of this phase is to get rid of excess sweatings as quickly as possible.

Day 6—Spread beans on resting floor at 6 a.m. to 7 a.m. (but not later) at the rate of one cubic foot of wet beans to 10 square feet of floor space. Do not spread the beans any thinner or any thicker. Spread evenly and stir by "walking" at 9 a.m. and 11 a.m. For a receiving box of 60-cubic-foot capacity, the resting floor should be 30 feet by 20 feet (for construction detail see "Design, Growth and Operation of Fermentary"). The objects of the resting phase are to stimulate the growth of yeasts and pulp maceration by these organisms, to evaporate excessive moisture and generally to get the bean into such a condition that temperature will jump sharply during subsequent fermentation. The resting phase will cause a reduction in acidity, but the level of acidity is maintained at a sufficiently high level to kill the bean and prevent putrefaction. Construct a box across the end of the resting floor (see Diagram No. 4) by standing two

walls 15 inches high on the floor. One wall should be on the very end of the resting floor and one 3 feet in from the end. This gives a long, shallow box 20 feet by 3 feet by 15 inches. (For further detail see "Design, Growth and Operation of Fermentary"). If required, the floor space in this box is available for beans during the resting phase. The bottom of this box **MUST** be drilled with half-inch holes on at least a four-inch-square pattern. These holes **MUST** be kept clear. Fill this box with beans off the resting floor at 1 p.m., gently firming the beans down to eliminate pockets of air. Thoroughly cover the beans with banana leaves and then bags. Good insulation is most essential. Double walls on the long, shallow box would be an advantage. The object of this phase is to create conditions which assist rapid temperature development and cause rapid and uniform killing of the beans.

Day 7—8 a.m. (or slightly later), transfer beans from long, shallow box to standard fermenting Box No. 1 (5 feet by 4 feet by 3 feet deep). Line all corners of this box with banana leaves and make sure that excessive pockets of air are eliminated as the box is filled. This box should have half-inch holes drilled in the bottom on a four-inch-square pattern. Cover the beans with banana leaves and bags. The object is to bring bean temperature to 45 to 50 degrees C. and to get the maximum possible destruction of the purple pigments (anthocyanins).

Day 8—8 a.m. (or slightly later). The No. 2 standard fermenting box should **NOT** be drilled with holes in the bottom. If it is, place a sheet of plywood without holes over the bottom of the box. Then turn the beans from Box No. 1 into Box No. 2. Cover with banana leaves and bags. The object during this day is to complete anthocyanin destruction and to prevent excessive aeration which could interfere with anthocyanin destruction.

Day 9—8 a.m. (approx.), turn the beans into Box No. 3. Line corners and sides of this box with banana leaves. This box **MUST** have holes drilled in the bottom on a six-inch-square pattern. The object on this day is to initiate oxidative changes in the bean.

Day 10—8 a.m. (approx.), turn the beans into Box No. 4. Line corners and sides of this

box with banana leaves. This box should **NOT** have holes drilled in the bottom. If holes exist, cover the bottom of the box with a sheet of plywood.

The object here is to carry oxidative changes to a stage further and inhibit any tendency to putrefaction by preventing reduction in acidity.

Day 11—8 a.m. (approx.), turn the beans into Box No. 5. Line corners and sides of this box with banana leaves. This box should have holes drilled in the bottom on a six-inch-square pattern. The object on this day is to carry oxidative changes further and reduce the level of acidity.

Day 12—8 a.m. (approx.), turn the beans out to dry. At this stage it is normal for a thin layer of beans from the very edges of the box to have a slightly "off" odour. If this layer is more than two inches thick (whatever the method of fermentation), the whole batch is likely to develop an "earthy" flavour, but it is impossible to prevent a slight tendency to putrefaction in a very thin layer of beans immediately adjacent to box walls.

Theoretical Basis

The method allows a period of viability of 32 to 36 hours. When the beans are placed in the long, shallow box following the short resting phase, temperature rises sharply to 42 to 46 degrees C. by the end of this phase 19 to 20 hours later. At the same time, cotyledon pH is brought almost to 4.5. The resting phase in combination with the initial shallow fermentation therefore quickly brings the beans to the conditions giving the maximum possible rate of anthocyanin destruction. The destruction continues during the next 48 hours during which oxygen uptake is held back. On the three remaining days of fermentation, oxygen uptake by the beans is encouraged but a safe level of acidity to prevent putrefaction is maintained. During this period, the beans will show an increasing amount of browning. Free liquid inside the bean will be muddy in appearance. When the beans are removed to the drier, the cotyledons should show pronounced browning just inside the bean skin and should have a bleached appearance at the centre. The more browning the better. Many beans will be completely brown.

Merits of Methods

(1) Reliability.

The method is not perfect but produces much more consistent quality than any other method yet devised. Chocolate-flavour development is greatly improved. The pattern of fermentation may show slight alteration as a result of pulp variation, but this is considerably less than with any other method. Method "C" does not therefore completely remove the causes of "dead ferments" but goes a long way towards it. At times when the "Old Technique" would produce beans of very low quality, the new technique would produce beans which would be acceptable to manufacturers. The method does not eliminate "underfermented" beans altogether, nor should it. The presence of 10 to 15 per cent. underfermented or "partly fermented" beans is the manufacturer's insurance against loss of flavour by over-oxidation. Badly underfermented beans are rare in Method "C". Using this method, there is a higher tolerance of underfermented beans. Even if the percentage rises above 20 per cent. there is very little loss of chocolate flavour. In this, Method "C" differs a good deal from other methods.

(2) Costs.

The installation of resting floors and the labour involved in spreading and regathering beans from the resting floor, might be expected greatly to increase processing costs. This is not so. Method "C" reduces fermentation time as compared with the "Old Technique" and labour costs for the two methods are almost the same.

The cost of installing resting floors is partly offset by the reduced number of fermenting boxes required and by the corresponding reduction in the size of the fermentary building. The saving of one or two days in fermentation time means that there is a potential increase in fermentary output of 12 to 25 per cent. The cost of the resting floors is fully justified by this and by the improvement in quality.

(3) Flexibility.

Generally speaking, it is recommended that instructions outlined above be adhered to. Under certain circumstances the method can be varied slightly to produce any desired modification in the pattern of fermentation. On a very wet day when evaporation rate is low, the

resting phase can be extended by one to two hours with advantage. Other steps in processing take place on schedule.

If the beans should occasionally remain very acid (and such an occurrence will be rare), this can be overcome by prolonging the resting phase for one to two hours. If the level of acidity falls too low and beans develop a marked "off" odour by the end of fermentation, in future ferments reduce the duration of the resting phase by one to two hours and omit the stirring during the resting phase. In the "off-crop" season when acid development is usually less, the same effect can be produced, without detriment to quality, by reducing fermentation time by one day.

As a general rule, the modifications noted here are unnecessary and growers are advised not to alter the method unless absolutely compelled to do so. Within this limitation, the method can be varied to produce any desired alteration in the level of acidity. Revert to standard practice as soon as conditions return to normal.

FERMENTING SMALL QUANTITIES

Methods used successfully in West Africa are inapplicable in New Guinea where the fermentation of small quantities of Trinitario beans is difficult. It is virtually impossible to turn out a consistently good product.

The problem arises when a plantation first starts to bear and for a short period during the "off-crop" season when the plantation is young. Wherever possible, it is recommended that small quantities of pods be disposed of to a neighbour who is producing on a reasonable scale or that neighbours pool their first harvests to give a satisfactory volume of beans.

Where this is not possible, the following method will give reasonable results:—

1st Day—Harvest.

5th Day—Break. Place the beans in one or more baskets as described for Method "B". Place the baskets in a "hot-box" in the sun as for Method "B", but with appropriate reduction in the length of the hot-box. Try to have this done by 9 a.m.

6th Day—Turn into a similar empty basket, 8 a.m. to 9 a.m.

7th Day—Turn into an empty basket, 8 a.m. to 9 a.m.

8th Day—Turn into an empty basket, 8 a.m. to 9 a.m. At 4 p.m., turn again into a basket lined completely with banana leaves (top, sides and bottom). Press the beans into the basket firmly.

9th Day—Turn into an empty basket at 8 a.m. to 9 a.m. At 4 p.m., turn again into a similar basket lined completely with banana leaves. Firm the beans in this basket.

10th Day—Turn into an empty basket at 8 a.m. to 9 a.m. At 4 p.m., turn again into a similar basket lined completely with banana leaves (top, sides and bottom). Firm the beans in this basket.

11th Day—Turn out on to trays and sun-dry slowly with continual stirring over a period of seven to ten days. The drying rate should be kept slow during the first three days, then wet the beans, rub on hessian or sacking and complete the drying slowly.

The method cannot be guaranteed, but the product is usually fair. Quantities as small as three to four cubic feet of wet beans can be fermented in this way. As more beans become available simply use more baskets. When four or five baskets can be filled, follow Method "B" until further increase in production permits the use of Method "C".

FURTHER DEVELOPMENTS

Work is continuing at Keravat to obtain still better control of fermentation. This work is based on Method "C". Small modifications and refinements may be recommended later on, but the basic fermentary equipment, layout and design will remain unaltered. It is most unlikely that major alterations will become necessary.

GENERAL NOTES

Adjustment of Bean Depth in Boxes

When breaking commences, it is difficult to judge the quantity of wet beans which will be produced, but generally speaking the planter will know whether one, two or three boxes will be required. Care should be taken to ensure that boxes are filled evenly to avoid having a small fraction of a box left over. It is far better to have two boxes just over half full than one full box and one with a very small quantity.

For Method "C", if a box is only three-quarters or half full, spread the beans over only a corresponding proportion of the resting floor.

Insert a false end wall in the long, shallow fermenting box so that beans are maintained at a depth of 12 inches to 15 inches. Steps to increase the depth of beans in the large, standard fermenting boxes will be unnecessary unless the depth falls below 18 inches. In such cases, insert a false end into these boxes as well so that a minimum depth of 18 inches is obtained. Such batches show a greater tendency to putrefaction by the end of fermentation. Accordingly, take steps to restrict aeration on the last day of fermentation. This can be accomplished by lining the bottom, sides and tops of the fermenting boxes with banana leaves. The aim is to reduce air penetration, not to eliminate it altogether. Alternatively, reduce fermentation time by one day.

"Turning"

The turning of beans from box to box should be accomplished without unreasonable delay. Beans should be well-aerated during the "turn". Large lumps and masses of beans should be broken up. To obtain uniformity, beans which were on top of the box should go on to the bottom of the next box. Thus, beans should be removed in layers rather than from one end of the box and then the other. As the beans are turned, they should be gently firmed down so that pockets of air are removed.

Cleaning

Boxes should be sluiced down and roughly cleaned with a scrubbing brush after every few batches. This is a good Saturday morning job. It is not necessary to use any fungicide.

Every few months (during the off-crop season), the fermenting boxes should be completely dismantled, scrubbed and sunned. There is no necessity for the use of fungicides, bactericides, etc., unless the boxes have become quite foul.

Use of Banana Leaves and Bags

Use of banana leaves has been widely recommended above. The leaves should not be used as a cover over the bottom of fermenting boxes unless this is explicitly advised.

Planters should establish an area of bananas convenient to the fermentary so that a good supply of leaves is assured.

At all stages of fermentation and irrespective of the method used, the beans in a fermenting

box should be covered with one or two layers of fresh, green banana leaves and then with at least two layers of bags. This conserves heat.

METHODS OF DRYING

Drying During "Flush-Crop"

For Trinitario beans, slow drying is essential. The best compromise between reduced drying costs, the minimum capitalization and the production of high-quality beans consists of hot-air drying on a platform-type drier for 24 hours, followed by an interruption of 48 hours in drying, followed by completion of drying in a further 24 hours in a rotary drier. This means that drying is completed in not less than four days, but drying equipment is occupied for only two days. Any one drier is occupied for only 24 hours. There is no bottleneck in processing at the drying stage and fermenting equipment can therefore be used to its maximum capacity.

This splitting of the drying between two drying units means that if they balance each other there is very little wastage of drying capacity due to shrinkage and loss of weight during drying. While both driers are occupied they are working at virtually full capacity. This is a more efficient arrangement than completing the drying of a batch of beans on the one drying unit where the unit is working at only half capacity by the end of drying, owing to shrinkage in volume and loss of weight. This is particularly marked with complete "rotary" drying. The capacity of such a drier is quite inflexible to begin with. If drying is spread out over four days, not only does this create a bottleneck in the flow of beans through the fermentary, but the use of the machine is inefficient. It is working at only half capacity by the end of drying.

With the combination of platform/hot-air drying and rotary drying, the loss of weight and shrinkage obtained on the platform drier means that the rotary drier need have a smaller capacity than if it were used alone. To put the proposition another way, if a rotary drier of given capacity is fully charged with half-dry beans (taken from a platform drier of correspondingly greater capacity) then its output in terms of dry beans from a single charge will be 66 per cent. higher than would be the case if it alone were used to dry wet fermented beans.

The "split-drying" increases the efficiency of the two drying units used. Drying should

not be accomplished in less than four days, but with the arrangement suggested the total amount of drying equipment required is reduced by half and the quality of the product is not greatly affected.

DETAILS OF PROCEDURE

1st Phase—On Platform/Hot-Air Drier

Place the wet fermented beans on the platform/hot-air drier. This unit should be equipped with a sliding roof so that the sun's heat can be used when available. Spread the beans uniformly. This should be completed by no later than 8 a.m. Use the sun throughout daylight hours if available. Continually stir the beans on the drier. No hard and fast recommendations regarding artificial heat can be made. This will depend on the intensity of solar heat and the thickness to which beans are spread. Artificial heat is required throughout the night, the intensity depending on the moisture loss during daylight hours and the rate of airflow. Beans should be stirred at intervals during the night to ensure that drying is uniform.

NOTE.—The object of this phase is to dehydrate the beans sufficiently to ensure that they will not putrefy or develop an "off" odour during the period of interruption to drying. To achieve this, fairly rapid drying is required over the 24-hour period. Excessive temperature must be avoided. The temperature of the beans themselves should never exceed 50 degrees C. (120 degrees F.). During this first 24 hours' drying, the cooling effect of rapid evaporation means that an air temperature of 160 degrees F. is safe. With a thick layer of beans, excessively high temperature and low rate of air-flow, the beans are likely to be "stewed" and will develop an obnoxious foreign flavour. If prolonged, this treatment will produce the objectionable "burnt" flavour.

The appropriate stage to interrupt drying is largely a matter of experience, but the following points should be noted :—

- (1) At the end of the first 24 hours' drying, the beans should be dry to the touch externally.
- (2) On cutting at this stage, there should be just a little free moisture within the beans. The cotyledon should be of a rubbery consistency. If the bean contains too much free moisture, this will come to the surface during the period of interruption and will cause putrefaction.

- (3) If, at the end of 24 hours, the beans are not quite dry enough, extend drying until they are. Reduce the duration of the interrupted period accordingly. If the beans are sufficiently dry before the 24 hours has expired, merely stop drying. Then go ahead with the interrupted phase on schedule.
- (4) If beans are over-dried during the first 24 hours, the benefit of the interrupted phase will be almost entirely lost and there will be a marked drop in quality.

2nd Phase—*Interruption*

Place two lightly but strongly constructed boxes so that they can be loaded conveniently from the platform drier. Each box must be big enough to accommodate a full charge from the platform drier. The boxes must be under cover. The dimensions of the boxes are not critical, but should be such that a depth of at least 18 inches of beans is obtained. It is better if the beans are warm or hot when placed in these boxes. The beans remain in these "holding" boxes for 48 hours. Do not prolong this period unless the pre-drying has been carried too far.

The holding boxes can be conveniently sited at the end of the platform drier or near the rotary drier. The best arrangement will depend on the particular fermentary design. If the processing units are arranged on a slope, labour is saved when the loading platform above the rotary drier is on the same level as or just below that of the floor of the platform drier. In this case, the holding boxes can be placed on the loading platform over the rotary drier.

In the flush crop, the normal sequence of events will be—

- (1) Empty one holding box (Box A) after 48 hours and charge the rotary drier.
- (2) The other holding box (Box B) will have been filled 24 hours before. These beans remain as they are.
- (3) Fill the empty holding box (Box A) with a full charge off the platform drier and recharge this drier.
- (4) On the following day, discharge the rotary drier and recharge from Box B. Fill Box B off the platform drier and recharge this drier. This can go on until crop pressure eases off.

As an alternative, beans can be bagged off the platform drier and held for 48 hours and then loaded into the rotary drier. Only clean, dry bags should be used for this purpose. Store the bags in a convenient position under good cover for the 48-hour period.

NOTE.—The object of the interruption to drying is to allow oxygen uptake by the beans. This causes them to go brown. It will have taken place to some extent during fermentation and during the first 24 hours' drying, but if drying is completed rapidly the enzyme responsible for the oxidative changes will be inactivated, and shrunken, "under-fermented" beans will result. Happily, the beans which most require further oxygen uptake tend to lose moisture at a slower rate than those in which oxygen uptake is already sufficient.

At the end of the interrupted phase, the beans will have softened to a rubbery consistency. The cotyledons should have become open-textured and brown, but perhaps with a residual purple or whitish cast. Externally, the beans will appear to be moister than when first placed in the holding box. A light speckling of surface mould or a whitish bluish on the beans' skins at this stage is not detrimental.

If the initial drying has been insufficient the beans will be quite mouldy and the odour will be mouldy, earthy or foul. This is most detrimental to flavour. It is quite easily avoided by giving sufficient pre-drying. At the end of the interrupted phase the beans should have a strong "cocoa" odour with a slight acid background. This acid background is desirable.

In the initial platform drying, the moisture content of the beans should be reduced to 20 per cent.

3rd Phase—*Rotary Drying*

Charge the rotary drier with equal loading of all compartments. Load two opposite compartments first and then the other two. The machine will remain balanced if the loading of opposite compartments is equal. Wet the beans in the rotary drier using built-in watering facilities or a hose through the doors. A considerable quantity of water is required. In a six foot by six foot rotary drier, 20 to 25 gallons of water are required for a full charge. In a seven foot by six foot, 30 to 35 gallons are required.

Fire the drier and start the drum. An initial air inlet temperature rising to 160 degrees F. is adequate. Air temperatures of 180 degrees F. can be tolerated for a few hours at the beginning of this phase only. If prolonged, the beans will develop a roasted or burnt odour and flavour. The initial drum speed should be two r.p.m. and this should be reduced to one r.p.m.

after four to five hours' drying. This speed can be maintained for 20 hours or slightly longer if necessary. If the beans have not been wetted in the drum, the advantages of rotary drying will be largely lost and there will be severe breakage unless the speed is reduced to $\frac{1}{4}$ r.p.m. or less.

After eight to 12 hours from the time of loading, reduce the air temperature to 140 degrees F. If the rate of airflow is such that this causes overheating of the beans, reduce the air temperature to 120 degrees F. Complete the final drying in 24 hours.

If the rotary drier is of the recirculating type (i.e., if the drum is enclosed in a box and air recirculated back through the heat-exchanger), wet the beans as above. Drum revolutions also remain the same. However, as bean temperature follows air temperature much more closely, air temperatures must be watched closely. The greater the air velocity, the more closely will bean temperature approach the temperature of the recirculating air. Where the rate of recirculation is very rapid, the temperature of the recirculating air should not exceed 130 degrees F. When the machine starts to operate, work with full recirculation until bean temperature reaches 120 to 125 degrees F. This should be achieved within an hour or two. Then open ventilators and dry at progressively decreasing humidity. Complete the drying in 24 hours. Better methods of handling driers of the recirculating type may be evolved as further information is obtained.

With most types of rotary driers, it is necessary to stop the drum two to three hours after the beans have been wetted and dislodge any beans sticking on to the perforated coreplate, against obstructions and in corners. With the method recommended, it is necessary to do this only once. After this the beans flow freely and do not stick.

NOTE.—The objects of the rotary drying phase are :—

- (1) To complete the curing of the beans.
- (2) To dehydrate the beans to 6 per cent. moisture.
- (3) To reduce skin percentage.
- (4) To impart an attractive appearance and polish to the beans.

The desired reduction in shell percentage cannot be obtained unless the beans are wetted down as described above. If the amount of water used is reduced the beans will become polished and the reduction in skin percentage will be less. It should be well noted here, however, that the addition of

too much water will result in excessive clogging. Even when the optimum amount of water is added (i.e., just enough to make the pulp quite soft) clogging will result if the perforations in the outer skin of the drum are not at least $\frac{5}{16}$ inch in diameter. With the recommended treatment, skin percentage can be reduced from more than 16 per cent. to 13 or 14 per cent.

Why wet the beans when the object is to dry ? The wetting permits reduction in skin percentage, reduces acidity, tends to "plump" the beans, prevents shattering and promotes a very even polish. Only the pulp is affected by the wetting. Moisture is not taken up through the bean skin. The effects of wetting last only a few hours. The "shipping" qualities of the beans remain unaffected by the treatment outlined above.

Softened pulp will gradually be extruded through the perforations in the drum during drying, but the holes will still permit the free flow of air. The grower should take no notice of this. It should not be touched until it is bone dry. It can then be easily scraped off in a few minutes as the drum revolves, leaving the perforations clear. It seems that mucilage or pulp is not extruded if the perforations in the skin of the drum are of the "drawn" type.

On the general question of "clogging", those rotary driers in which there are no internal obstructions are almost free of this problem. However, any internal obstructions become a focus around which wet beans will gradually build up. In the six foot by six foot rotary drier at Keravat, all baffles in each compartment were removed. In addition to causing clogging, these baffles had the effect of crashing the beans about inside the drum, leading to shattering. Removal of the baffles did not adversely affect the machine in any way, nor has it affected the rate or uniformity of drying. Similarly the original perforations in the outer skin of the drum have been enlarged to a diameter of $\frac{3}{8}$ inch. This has tended to prevent clogging and restriction of airflow and has also had no adverse effects. Enlargement of all perforations to $\frac{3}{8}$ inch carries no risks with a six foot by six foot rotary drier, but there may be a risk of over-weakening in the case of a seven foot by six foot drier where the effect on the overall architecture is more pronounced. The manufacturer's advice should be sought on this point.

If the drum of the rotary drier is not completely filled so that there is an air-space in each compartment, the movement of the beans within

the compartment reduces the tendency to clog. To accommodate a full charge off the platform drier, the choice may be between using a six foot by six foot rotary drier completely filled, or a seven foot by six foot drier, leaving a larger air-space. Under these circumstances, better results will be obtained with the seven foot by six foot drier. With a 40 foot by 20 foot platform/hot-air drier, the out-turn of half-dry beans can be accommodated in a six foot by six foot rotary drier, but the rate of drying and reduction in skin percentage will usually be faster in a seven foot by six foot rotary drier.

Drying During "Off-Crop" Season

When production eases off, the whole pace of drying can be reduced. This will be reflected in slightly better quality beans. As soon as the crop-pressure falls, the initial drying on the platform drier can be spread over 48 hours instead of being hurried along in 24 hours. This does not mean continuous operation of the drier with artificial heat for this period. Heat can be applied when necessary in short bursts. Gentle heat is required on the first night up to 10 p.m. to 11 p.m., after which the drier can be shut down. Use the sun or artificial heat the next day until the beans are surface dry. Then shut down the unit and heap the beans on the platform under cover.

On the third morning, charge the rotary drier and apply steady heat for 36 to 40 hours after first wetting the beans in the drum. Shut down over the second night. Then complete the drying during the next 24 hours.

With this method, the holding boxes are bypassed. Their use during the flush crop enables the grower to double the output of his drying equipment, but this is not necessary in the off-crop season.

GROWING UP WITH COCOA DRIERS.

The arrangement of driers described above is the final arrangement. When it can no longer cope with production, the arrangement can be duplicated either gradually or *in toto*, depending on anticipated increase in production. It is also possible to build up the original installation according to needs.

When the plantation first begins to bear, a start can be made with a 40 foot by 20 foot sliding roof sun-drier. It will accommodate the

equivalent of 15 cwt. of dry beans and will handle about 15 tons of dry beans per annum.

As production expands, the sun drier can be converted to a "forced-hot-air" platform drier, provided this was allowed for in its original design. Its capacity per full charge will then be equivalent to a ton and a half of dry beans and its annual output will be about 45 tons.

When this production is outgrown, a rotary drier and holding boxes as described above can be installed. This arrangement is then theoretically capable of handling (disregarding management problems for the moment) a crop of 190 tons per annum if the equivalent of a ton and a half of dry beans is coming forward for drying five days in every week during the flush crop (if 8,500 lb.—three boxes each of 52 cubic feet—of wet beans reach the fermentary on each of the five days in each week). Management problems will reduce this figure, but the potential is there.

With the final arrangement, drying equipment can be fully exploited only with daily "breaking", but various factors may prevent this. As the frequency of breaking diminishes, so the capitalization required in driers increases. Fermentary capacity is discussed more fully at a later stage. It is more relevant at this point to describe the best methods of utilizing the various types of driers at different stages of growth before the final arrangement is achieved.

Use of Sun Driers

Get the fermented beans on to the sun-drier as early as possible in the morning. Spread the beans evenly and stir by "walking" every hour or so throughout the day. Do NOT heap the beans on the first night. On the second day, stir as before and pull the roof over the beans for a few hours in the middle of the day. Heap the beans under the roof on the second night. On the third day, spread the beans in the sun until 10 a.m. to 11 a.m., then heap, wet and "dance". "Dancing" imparts an attractive polish to the beans and aids the curing process. Use sufficient water just to wet and soften the pulp on all beans. For efficient "dancing" at least six labourers are required for about half an hour. Four labourers should keep pushing the beans into a heap while the other two vigorously jog up and down with their feet. Do not allow the heap to become flattened or beans will be damaged and avoid getting excess water over the drying floor. Spread the beans out in the

sun again. Heap the beans under the roof on the third night only if they are surface dry and not likely to mould. Complete the drying gradually in the next four days. Rate of drying can be reduced by increasing the thickness of beans on the floor.

The above procedure applies during fine, sunny weather. Adjust the process according to weather conditions. Do not heap the beans under the roof on the second night if the rate of drying has been slow and the beans are still "tacky" to the touch. Do not "dance" on the third day, but defer until the fourth or fifth day if the rate of drying has been very slow. The beans should be at the "soft leathery" stage when "danced". Do not "dance" on a day which is overcast or if rain threatens. At all points, be guided by the odour of the beans. If there is any suggestion of an earthy, foul or mouldy odour, do everything possible to increase the rate of drying. While the "acetic" odour remains, a slow rate of drying is advisable. Do not overload the sun-drier as this will inevitably lead to putrefaction within the first two or three days.

High-quality beans can be produced by sun-drying until prolonged bad weather intervenes. It then becomes impossible. Good sun-drying is a fine art and constant supervision is required.

Use of the Platform/Hot-air Drier

The point is reached where the grower has a sliding roof/platform/hot-air drier, but no rotary drier. In the "off-crop" season, it may not be necessary to use artificial heat except during bad weather. The unit is used primarily as a sun-drier. Artificial heat can be given in short bursts when required.

During the "flush-crop", drying should not be completed in less than four days. If a full charge of beans remains on the drier for four days, this means that pods can be broken only once every four days. Using the drier this way means that a production of 45 tons per annum can be handled, provided fermentary equipment is such that it can be fully charged. It would be possible to double this by installing holding boxes so that a given charge occupies the drier for only two days. The method would be as described above, except that the final day's drying would take place on the platform drier instead of the rotary drier. This procedure would make it possible to "break" on three

successive days. There would be no more breaking during the next three days after which the process could be repeated. The disadvantage of this procedure lies in the extra handling required.

It is inadvisable to have two different batches of beans at different moisture contents on the drier at any one time. Treatment required for one batch usually does not suit the other. If one batch which is half-dry is pushed to one end of the drier and a fresh charge placed on the vacant space, the fresh charge will dictate the necessity for fairly hard drying. While this is being done, it is impossible to stir the deeply spread, half-dry beans. The result will be scorching or at least "over-drying" of portion of these beans while others will remain moist. It is impossible to get an even rate of drying and the object of getting greater output will be defeated.

In any form of hot-air drier, it is most important to keep the beans moving. Do not allow them to stick to the floor. If this happens, a fragment of shell is torn off when the beans are gathered up. Such beans are then subject to insect infestation and internal mould. If the drier has hot or cold spots, reverse the position of the beans regularly.

Excessive temperatures must be avoided at all costs. Where it is desired to increase the rate of drying beyond that given at 160 degrees F., increase the airflow (if this is possible) NOT the temperature. Hard and fast recommendations regarding air temperature cannot be made. The tolerance depends on the rate of airflow and the moisture-content of the beans. High air temperatures at the beginning of drying are less dangerous than later. When the beans become half-dry, they tend to heat up and high air temperatures will cause scorching or roasting. As a rough guide, bean temperature should never rise to the point where a handful of beans feels uncomfortably hot. Bean temperature should not exceed 50 degrees C. (122 degrees F.).

Use of Rotary Driers

(When used alone or in conjunction with sun-driers. For use in conjunction with hot-air driers, see above.)

A few growers have equipped themselves with rotary driers for use alone or in conjunction

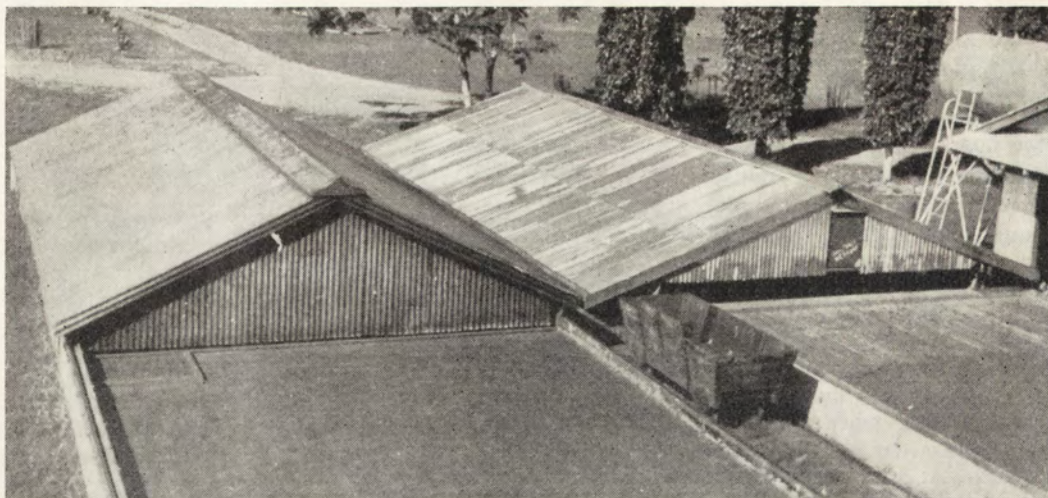


PLATE 5.—*Sliding roof platform driers at Keravat.*

with sun-driers. In the latter case, to complete drying in not less than four days, there are three possible alternatives :—

- (a) One day's sun-drying—no re-wetting plus three days' rotary drying.
- (b) Two days' sun-drying—light re-wetting plus two days' rotary drying.
- (c) Three days' sun-drying—moderate re-wetting plus one day's rotary drying.

All these methods will give equally good results. Two days' sun-drying plus two days' rotary drying will give the greatest output since this will permit "breaking" every second day. In rough terms, it will require two standard sun-driers (dry bean capacity, 15 cwt.) to balance one six foot by six foot rotary drier, or three standard sun-driers to balance a seven foot by six foot rotary drier. For this arrangement, use the rotary driers as described above.

There is no objection from a quality point of view to complete rotary drying provided this is accomplished in not less than four days. Wet fermented beans produced by the "Old Technique" or Methods "A" or "B" will usually cause serious clogging of a rotary drier. Such beans should get some pre-drying before being placed in a rotary drier. With Method "C", beans can be placed direct in the rotary drier. Even with this method, however, it is necessary to stop the drum once after a few hours' drying and dislodge from corners and crevices any

beans which are not moving freely within the drum. At no stage are the beans wetted.

If the beans are completely rotary dried (Method "C" only), the machine is normally loaded at 8 a.m. to 9 a.m. It should be run continuously until 10 p.m. to 11 p.m. on the following day and then shut down. It need run for only 10 to 12 hours on each of the remaining two days to complete curing and drying.

No matter how a rotary drier is used, it is an advantage to turn the drum at two r.p.m. for the first few hours of drying. After this, drum speed depends on how long the beans are to remain in the drum :—

For four days' rotary drying—Drum speed, $\frac{1}{4}$ r.p.m.

For three days' rotary drying—Drum speed, $\frac{1}{2}$ r.p.m.

For two days' rotary drying—Drum speed, $\frac{3}{4}$ r.p.m.

For one day's rotary drying—Drum speed, one r.p.m.

NOTE.—This assumes no internal baffles ; if there are any, halve the speeds. If perforations in the skin of the drum are of the "drawn" type, the speeds can be doubled. This variation is necessary to achieve the desired reduction in skin percentage without causing damage to the bean skins.

Complete rotary drying is uneconomical. If it extends over a period of four days, an expensive machine is tied down for this period and

during the last two days of drying it is working at only half capacity owing to shrinkage in volume and loss of weight. Complete rotary drying is not recommended.

DRIER CONSTRUCTION AND DESIGN

Sun-Driers

- (1) The drier should be low for ease of loading and unloading.
- (2) It should have adequate ventilation below the drying floor.
- (3) The floor should be firm and substantial so that several labourers can work on it. For this reason, a sliding roof over a fixed floor is preferable to sliding trays under a fixed roof.
- (4) The sliding roof should be easily managed. RidgECapping should be "jacked" a few inches to prevent condensation on the under-surface of the roof during the night. The under-surface of the roof should be painted with acid-resisting paint.
- (5) There should be sufficient clearance between the roof and the floor to enable labourers to work under the roof in wet weather.
- (6) All ties, joists and end-walls of the roof should be high enough to clear beans heaped on the floor to a depth of about a foot.
- (7) The building must be structurally sound.
- (8) Experience at Keravat indicates that properly treated galvanized iron roof lasts better than aluminium. The evident advantages of the latter are generally outweighed by its lack of durability.

Platform/Hot-air Driers

I. Kiln Type

Satisfactory methods of operating this type of drier have been fully described by Henderson (1954). If they are used carefully and judiciously, high-quality beans can be produced, but as a type kiln driers are not recommended. The types in common use throughout the Territory are difficult to control, costly to operate and lend themselves too readily to abuse. Virtually all the "hammy" beans and 90 per cent. of the "burnt" beans now being produced come from this type of drier. These objections can be overcome if the drier is properly designed and properly managed. The main points to remember are :—

- (1) A kiln-type drier has a fixed maximum capacity. No attempt should be made to increase this capacity by raising the temperature above normal limits. As the rise in temperature cannot be balanced by greatly increased airflow, the beans will "stew" and burn.
- (2) Even with careful management, "burnt" beans will inevitably be produced if the kiln pipes are too close to the drying floor or if the chamber under the drying floor is not suitably baffled to break up convection currents of very hot air. Kiln pipes should not at any point be closer to the beans than five feet.
- (3) The slightest smoke-leak in the kiln pipes will cause the development of a "hammy" flavour in the beans.
- (4) Having regard to the minimum construction requirements, the close supervision required, the fuel consumption and the difficulty of control, kiln-type driers are just as costly as the more efficient types of driers, if not more so. Kiln-type driers are the least satisfactory of all in regard to heating efficiency.

II. Forced-air Type

With the much more rapid and controllable rate of airflow given by this type of drier, a sufficiently high rate of drying can be obtained without using high temperatures. This obviates the risk of "burning". Furthermore, there is very little risk of "hammy" flavours being developed. As long as the heat-exchanger is kept in good condition, there is no risk at all.

Important points in design are :—

- (1) Structural soundness and mechanical simplicity.
- (2) Efficient heating of air within the temperature range required and within the range of variability of air velocity.
- (3) The drier must be so designed that the rate of drying can be controlled. To suit the system recommended above, the maximum requirement is that the unit must be able to reduce the moisture content of 7,000 lb. of wet fermented beans to 20 per cent. in 24 hours without any assistance from the sun. The ability to vary temperature (and also airflow if possible) is necessary when the unit is working below its maximum capacity.

- (4) The drier should be so designed that loading and unloading are rapid and easy. This will be so if the floor is low and there is a sliding roof.
- (5) There should be no hot or cold spots on the floor. The drying rate of beans spread over the floor must be uniform.
- (6) A sliding roof is essential in reducing operating costs and in providing a certain margin of safety in the rate of drying and in the event of mechanical failure. The sliding roof should travel far enough off the drying platform to ensure that its shadow never falls on the drying floor.

Rotary Driers

The following points are important :—

- (1) To suit the drying system described above, the rotary drier must have the capacity to reduce the moisture content of 4,000 lb. beans at 20 per cent. moisture to six per cent. moisture in 24 hours.
- (2) Structural soundness, durability and "finish" on the machine are even more important than with any other type of drier.
- (3) The machine must resist serious clogging. These requirements have been noted above.
- (4) Variable drum speed is a great advantage, but not absolutely essential, provided the grower gets the appropriate speed to suit his method of drying and provided he does not depart from this. However, in addition to this one main operating speed, it is an advantage to have also a speed of two r.p.m. There will be times during the off-crop season when the rotary drier is used at half capacity or less. A small charge receives correspondingly greater wear during drying. Damage can be prevented if a slow drum speed of $\frac{1}{4}$ r.p.m. or less is available. Without having variable speed, much the same effect can be obtained by running the drum intermittently. This is necessarily wasteful of fuel.
- (5) There should be no significant temperature gradient from one end of the drum to the other. Uneven drying in different parts of the drum is a serious defect.
- (6) A recirculation system offers certain advantages. The humidity control makes it possible to stimulate the final "curing" and "plump" the beans. The system gives a substantial fuel economy. Actual figures

should become available in the near future. Further experience is required before it can be determined whether conventional materials involved in the recirculation system will be affected by corrosion from acetic acid vapour. However, with the drying system recommended in Method "C", acid vapour has largely disappeared by the time the beans are placed in the rotary drier. After rewetting, it may be desirable to run the machine for a short time without recirculation to drive off remaining acid. Parts which are exposed to acid vapour should be treated with some acid-resisting compound.

Note on Oil Firing

In producing heated air, the two factors to be considered are efficiency and economy. With the control given by well-designed fuel injectors, there is a decided gain in efficiency from oil-firing as compared with the more clumsy stoking with solid fuel. There is less fuel wastage where the amount of fuel injected can be controlled within precise limits to suit the capacity of the particular heat-exchanger. Air temperature can be controlled with a high degree of precision.

However, the choice of oil-firing or solid fuel will be determined almost wholly by comparative costs and the level of production. Frequently, but not invariably, availability and low cost are on the side of solid fuel. Equally frequently, the cost of solid fuel is underestimated. On the side of oil-firing is reliability, control, reduced supervision and labour costs and prolonged life of the heat-exchanger. The margin between the two alternatives often depends on whether fuel-oil can be delivered in bulk or not.

For the smaller and the intermediate-sized producer, oil-firing is strongly recommended where costs approach equivalence. The large producer (say 100 to 120 tons per annum or more), who is in no position to make sudden alternative arrangements for the drying of large quantities of beans in the event of fuel shortage, has almost no alternative. He must oil-fire or face either increased costs or chaos unless he has exceptionally favourable supplies of solid fuel.

It requires the burning of a ton and a quarter to a ton and a half of *Leucaena glauca* to dry enough wet beans to give one ton of dry cocoa, using a standard type of six foot by six foot rotary drier.

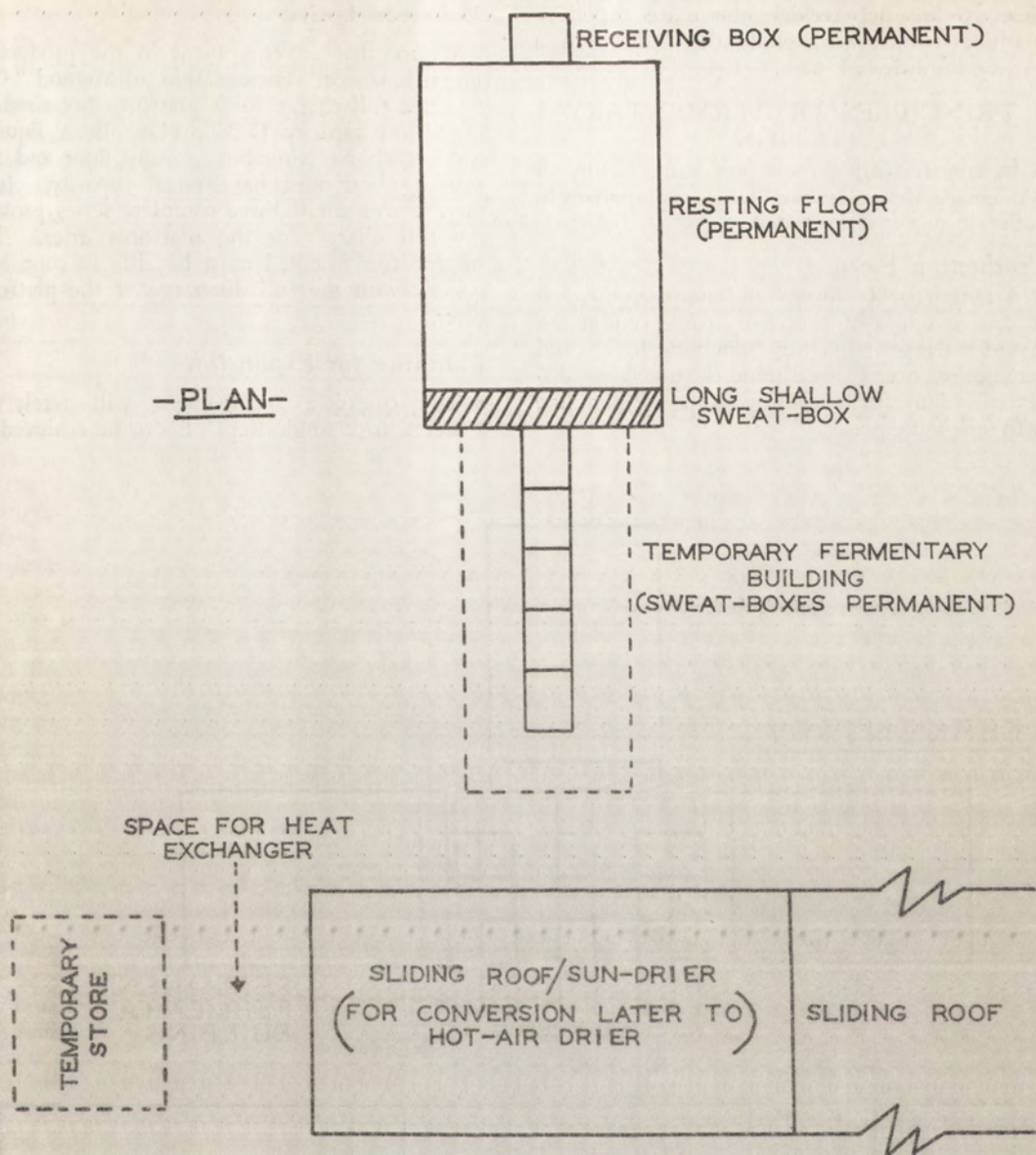


DIAGRAM IV.—Processing plant, Stage 1.

CLEANING AND WINNOWING

When the beans have been dried down to six per cent. moisture, it is essential to remove empty skins, very small shrivelled beans, rubbish and "doubles". Labour costs in doing this by hand are very high and it is a job which lends itself to complete mechanization.

However, none of the three types of winnowers which have been tried at Keravat can be recommended. A fourth type is to be tried in the near future.

Growers will be advised as soon as a satisfactory machine is tested. It should be noted

that we are not seeking the more expensive machines which will grade the beans into a variety of different sizes.

PRINCIPLES OF FERMENTARY DESIGN

In constructing a cacao-processing factory or fermentary, the following points are important to both efficiency and economy :—

Production Flow

Arrange for buildings and units required at successive stages of processing to be contiguous. Avoid a design requiring "doubling back" and cartage of beans over unnecessarily long distances. Aim for a continuous production line with no bottle-necks.

Balanced Units

Ensure that all equipment in the production line is balanced. For example, in Method "C", to get a full charge for a platform/hot-air drier of $1\frac{1}{2}$ -ton capacity D.B.E. (Dry Bean Equivalent), each receiving box, resting floor and fermenting box must have equal capacity. It is then convenient if three complete series provide the full charge for the platform drier. The rotary drier installed must be able to cope adequately with the full discharge of the platform drier.

Planning for Expansion

The complete arrangement will rarely be achieved in a single step. It can be achieved in

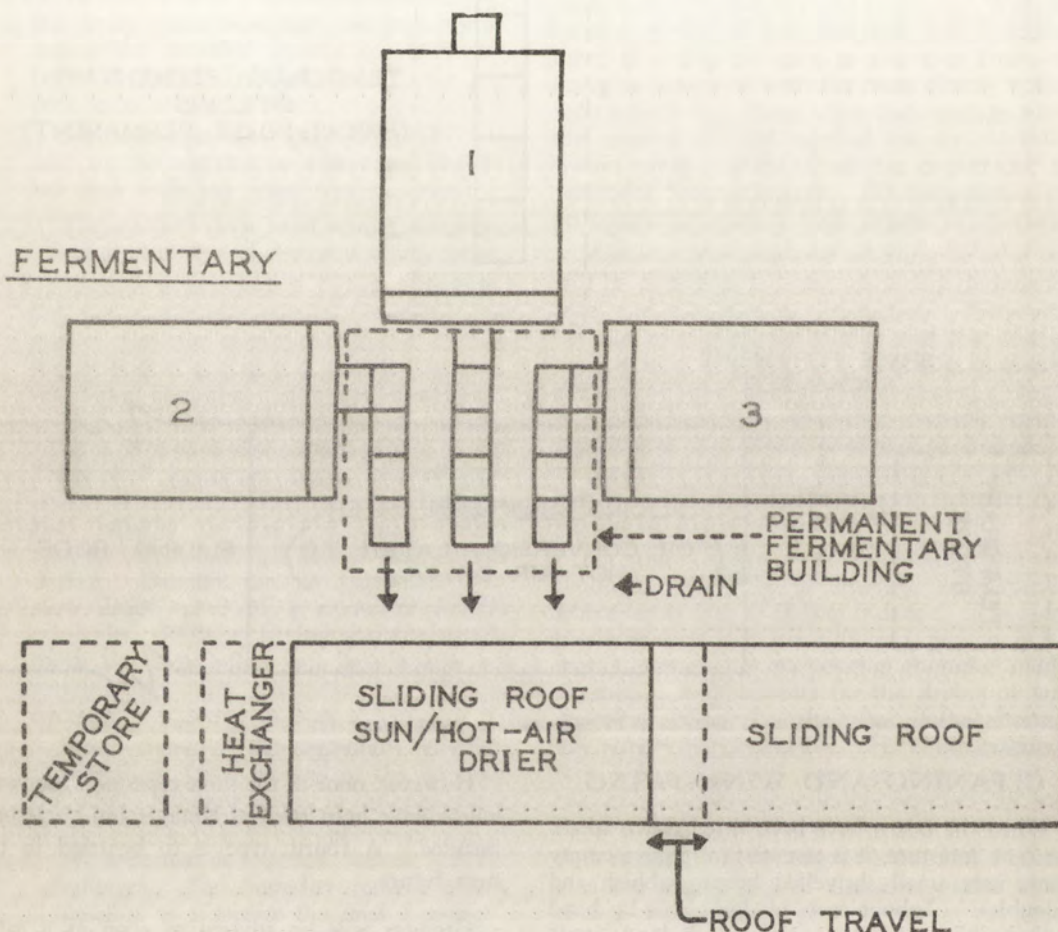


DIAGRAM V.—Processing plant, Stage 2 (water storage tanks not shown).

easy stages. The fermentary should grow according to a master plan, so that growth does not lead to chaos and high processing costs.

Convenient Siting

If possible, the fermentary should be centrally situated on the plantation, or at least at a point where the majority of plantation roads converge. Buildings should be arranged so that they do not cast shadows on sun or sun/hot-air driers. Natural slopes should be utilized wherever possible to give a gravity feed through the fermentary. However, if the choice is between an inconvenient site with a slope and a convenient site without a slope, use the convenient site.

The benefit of a gravity feed is appreciable only at certain stages of processing. The level of the resting floor should be just above the level of the top of the first fermenting box. The arrangement of fermenting boxes in tiers has certain disadvantages. There is a useful gain if the level of the final fermenting box is above the level of the floor of the platform drier. By far the greatest gain is obtained if the loading platform over the rotary drier is a little lower than floor level on the platform drier. When production is high, the savings in labour resulting from the judicious use of slopes is considerable. If beans have to be carried to the highest point by hand to get the satisfaction of pushing them down an artificial slope, there can be no gain whatsoever.

DESIGN, GROWTH AND OPERATION OF FERMENTARY FOR METHOD "C"

The logical way in which drying facilities can be expanded to meet increasing production has been described above. It was noted that it is possible to begin with a sun-drier and then convert this to a forced-hot-air/platform drier. At a later stage, holding boxes and a rotary drier may be installed.

The logical concurrent expansion of fermenting equipment can now be considered.

Stage 1

Equipment—

- One Receiving Box—60-cubic-foot capacity.
- One Resting Floor (complete with shallow fermenting box)—30 feet by 20 feet.
- One Battery of five fermenting boxes—each box five feet by four feet by three feet deep (temporary roof over these boxes).

One Sliding Roof/Sun-Drier—40 feet by 20 feet (suitable for conversion to hot-air in Stage 2).

Capacity—

About 15 tons dry beans per annum.

Stage 2

Equipment—

- Three Receiving Boxes—each of 60-cubic-foot capacity (two not shown in Diagram V).
- Three Resting Floors—each 30 feet by 20 feet (each complete with shallow fermenting box).
- Three Batteries of five fermenting boxes as above.
- One permanent fermentary building (28 feet by 25 feet, approximately).
- One Sun Forced Hot-air, Sliding-roof/Platform Drier—40 feet by 20 feet, approximately (holding boxes optional).
- One Temporary Store for dry beans.

Capacity—

The maximum frequency of breaking will be once every four days. Theoretically, therefore, the above arrangement is capable of an output of a ton and a half of dry beans every four days or around 90 tons per annum. However, as cropping is anything but regular throughout the year, this rate of production will be given during the flush-crop by a plantation which produces only 45 tons for the whole year, which is therefore the actual capacity of the above arrangement. The equipment will work at well below its maximum capacity during the "off-crop" periods. This is inevitable and unavoidable. Yet the fermentary must be planned to cope with the flush and not the average monthly crop.

As noted above (See *Growing up with Cocoa Driers*) this capacity can be greatly increased by installing holding boxes so that a given batch occupies the drier for two days instead of four days. This then permits more frequent breaking and better use is made of fermenting equipment.

Stage 3

At this stage, all units become perfectly balanced.

Equipment—

Fermenting equipment remains unchanged.
Hot-air Drier remains unchanged.

Two Holding Boxes—each of 130-cubic-foot capacity (eight feet by six feet by two feet nine inches suggested).

One Rotary Drier—a six foot by six foot rotary drier will barely cope—a seven foot by six foot rotary gives a safety margin.

One Building over Rotary Drier, holding boxes, winnower—also to provide bagging space—extend to form store for dry cocoa beans (at least 45 feet by 20 feet).

Capacity—

Disregarding management problems for the moment, this arrangement is capable of an out-turn of a ton and a half of dry beans every day of the year if the wet beans are forthcoming. Unfortunately, management problems cannot be disregarded and the beans will not be forthcoming. If the equivalent of a ton and a half of dry beans enters the fermentary five days in each week during the flush crop, this gives a theoretical capacity of 390 tons per annum or an actual capacity of 195 tons per annum. If the equivalent of a ton and a half of dry beans enters the fermentary four days in each week during the flush-crop, this gives a theoretical capacity of 308 tons per annum which corresponds with an actual capacity of 154 tons per annum. Breaking three days in each week will give an actual capacity of 117 tons per annum. The capacity at Stage 3 depends entirely on the frequency of "breaking". Figures given on capacities will also vary according to the intensity of the "flush-crop".

Management

When in constant operation, the timing of the various operations in the fermentary at Stage 3 becomes more difficult and requires greater skill in management. The fermentary will have to work to a strict schedule. The rotary drier should be discharged and recharged from a holding box by 7 a.m. The platform/hot-air drier should be discharged to a holding box and recharged from the three final fermenting boxes by 8 a.m.

Beans in all stages of fermentation should move forward by one step and, although not critical, this should be completed by 10 a.m. The resting floor will have been vacant since 1 p.m. the previous day and should receive a fresh charge at 6 a.m. This will be transferred to the long, shallow fermenting box on the end of the resting floor at 1 p.m.

Throughout day and night, both driers will require checking. All machinery must receive any necessary maintenance during operation. The fermentary must be kept clean and orderly. Dry beans must be winnowed, weighed and bagged. This is normally an afternoon job.

When operating during the flush-crop, one of the biggest difficulties is to balance the rate of harvesting with processing potential. Where the fermentary has a potential intake of a ton and a half D.B.E. per day, this requires the harvesting of some 37,000 pods daily. Depending on the terrain and compactness of the plantation, this will require a harvesting gang of 20 to 25 labourers. In practice it is safest to harvest a surplus and "break" into containers of known capacity. In this way, breaking can be stopped when fermentary capacity is reached. Surplus pods can go into the next day's breaking.

Obviously, a fermentary could not operate continually on this basis. There is no particular problem during the "off-crop" season. Even during the "flush-crop" it will be impossible to accept a full fermentary load on more than five days in each week. A break is necessary to allow cleaning of fermenting boxes, resting floors, rotary drier, etc., maintenance of machinery, etc., but the longer the breaks the lower the output and the greater the capitalization required to handle the flush-crop.

Water Supply

As output grows it becomes more necessary to have a reliable water supply at the fermentary. At Stage 1, the water consumption of the fermentary will be less than 50 gallons a day. At Stage 2, the average consumption will be more than 100 gallons a day. At Stage 3, it is estimated that 200 gallons a day will be the average requirement. A head of about 4 to 5 lb. p.s.i. is sufficient for normal fermentary operations, but higher pressure is an advantage.

Labour

Reduction in labour costs by utilizing slopes, a convenient lay-out and labour-saving devices

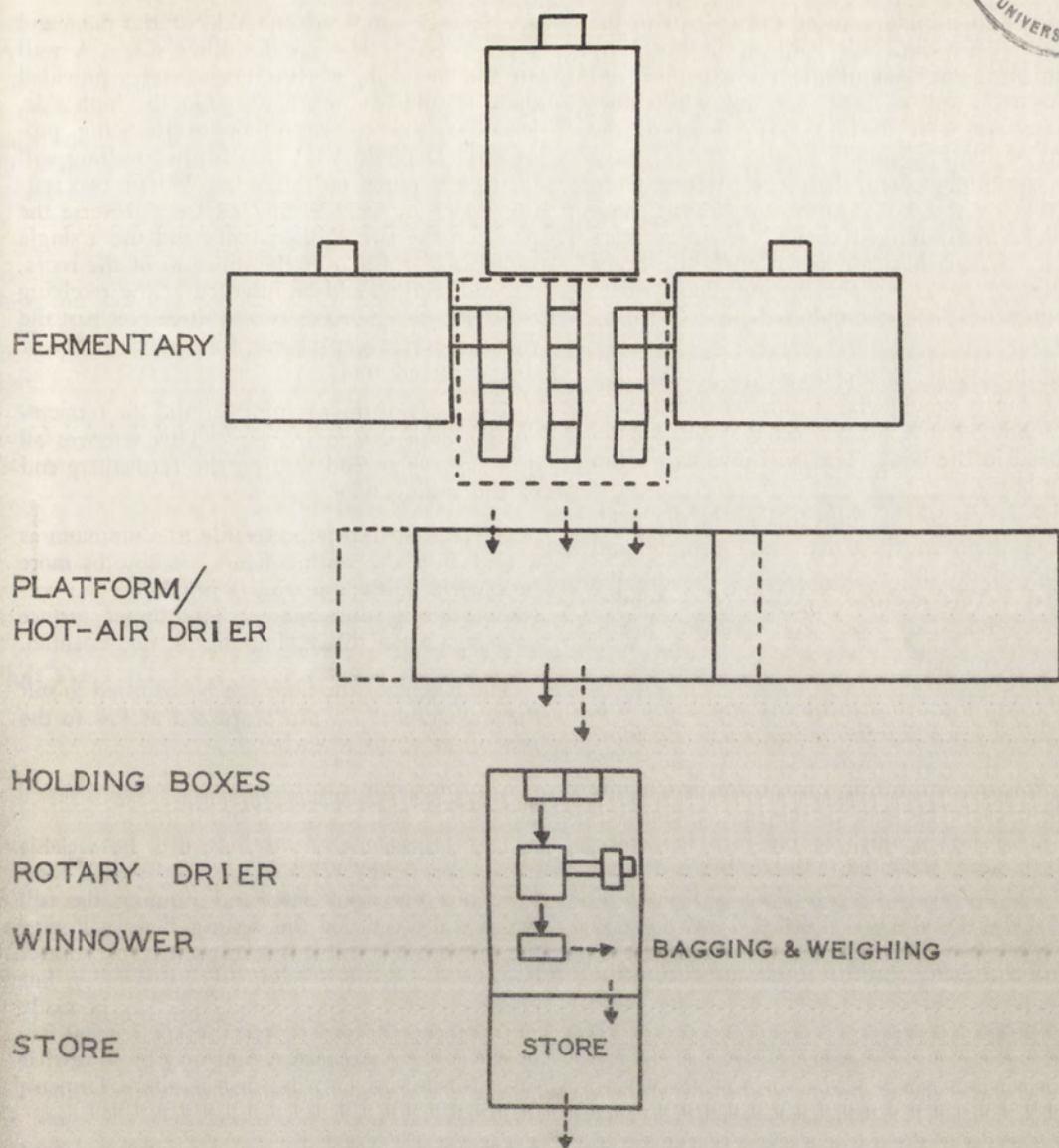


DIAGRAM VI.—Processing plant, Stage 3 (water storage tanks not shown).

will pay handsome dividends. The labour required at the fermentary will vary according to these factors. As a rough guide, one labourer will be required in the fermentary for every 10 tons of dry beans produced per annum. Labour costs are relatively much higher during the "off-crop" season.

Construction Detail

1. Receiving Boxes

Use one-inch seasoned hardwood. Dressing is not necessary but facilitates cleaning. Make the boxes durable. Drill the bottom of the box with half-inch holes on a two-inch-square pattern.

Sweatings go straight into an open drain in the ground. Place the box hard up against any convenient point around the resting floor and see that it is well covered in a way which does not interfere with loading. The level of the bottom of the box should be the same as, or a few inches higher than, that of the resting floor. The side of the box against the resting floor should be firmly hinged at the base, using brass hinges. When this side is lowered, the beans are pushed out over the resting floor where spreading can be accomplished in 10 to 15 minutes.

The dimensions of the receiving box are not critical, but it should give a capacity of 60 cubic feet. Only 52 to 55 cubic feet of beans should be placed in the box. This will give half a ton of dry beans.

If beans are broken into baskets in the field, they can drain in these baskets overnight and be dumped on the resting floor at 6 a.m. the next day. This requires a considerable number of baskets but does away with receiving boxes.

2. Resting Floor

Only very light construction is required. It is sufficient to place bearers 10 feet apart and joists at four feet. Place two extra joists under the long, shallow fermenting box at the end of the resting floor. The floor of the resting floor can be of undressed six-inch by one-inch hardwood but cleaning is facilitated if the timber is dressed on the upper surface. The planks should be spaced at an eighth to a quarter of an inch so that water used in washing can run through to the ground. There are no sweatings during the resting phase and no provision has to be made for drainage.

The resting floor should be 30 feet by 20 feet for each charge of half a ton D.B.E. Where a double floor is required, two separate 30 foot by 20 foot floors should be used in preference to one 40 foot by 30 foot floor. The object is to achieve the maximum possible air-movement over the floor so there is a decided advantage in keeping the floors long and narrow.

The roof should be kept as close to the floor as possible to give the maximum build-up of air temperature over the beans. This also reduces walling costs. It is sufficient to have just enough clearance between roof and floor for convenient working. Probably the best arrangement is to have a skillion roof giving four-

five-foot clearance on one side of the floor and seven to eight feet on the other side. A wall on the low side is then unnecessary, provided there is sufficient overhang. On the high side, install a six- to seven-foot overhanging projection (Diagram VII). No further walling will then be required on this side. Where two resting floors are parallel and adjacent, reverse the pitch on the two skillion roofs and use a single well-jacked ridge over the junction of the roofs. An end wall should be installed at the receiving end. Project the roofs two to three feet past the ends. Leave a gap of one foot between top of end wall and roof.

The roofs of the resting floor and the fermentary building should overlap. This removes all necessity for an end wall on the fermentary end of the resting floor.

Galvanized iron is preferable to aluminium as a roof over the resting floor. It absorbs more heat, is more durable and is not subject to corrosion during this phase. The upper surface may be painted black, but this is not essential.

The height of the floor can be adjusted to suit the topography. It can be placed as low to the ground as 12 to 18 inches.

3. Long, Shallow Fermenting Box

The dimensions of this box may be variable except for depth, *which is critical*. A three-foot-wide box one foot deep and running the full width (20 feet) of the resting floor will give the required 60-cubic-foot capacity. A shorter box 15 inches deep is equally satisfactory, but under no circumstances should the box be made any deeper. A box 10 feet by six feet by one foot would be satisfactory and may be somewhat easier to unload into the first standard fermenting box.

The floor of this box is formed by part of the resting floor and must be drilled on a four-inch-square pattern with half-inch holes. These holes must be kept clear. Heat will be conserved if the box is double-walled. At Keravat, this box is double-walled using tongue-and-groove flooring. For convenience of loading into the first standard fermenting box, the outer wall of the shallow fermenting box may carry a gate, hinged at the bottom (brass hinges), so that when lowered it serves as a chute into the first standard fermenting box.

4. Standard Fermenting Boxes

These boxes should be constructed in batteries of five. Construction recommended is the same as described by Henderson (1954) with the exception that the "Vee Drain" running the full length of the battery, while desirable, is not essential. There are no "sweatings" from the beans in these boxes. Drainage is required to take away water used in washing. The fermenting boxes must be raised some four inches above the concrete floor so that air can be taken in through the bottom of the boxes. If the whole floor of the fermentary building has a slight fall to a single open drain (Diagram V) at the front of the fermentary building, this provides adequate drainage. Sluice the whole floor regularly.

ridge capping is raised two inches. If skillion, leave a gap along the top of the highest side to permit the escape of acid-laden air. The underside of the roofing iron should be painted with acid-resisting paint *before* it is put up.

Construct the fermentary building in such a way that cooling winds do not increase radiation losses from the fermenting beans, but allow for some air-movement to remove acid vapour. A one-foot space is sufficient between the top of any walls which may be required and the roof.

6. The Sun/Hot-air Platform Drier

Site as close to the fermentary building as possible without getting a shadow falling on the drying floor (Diagram V). If the drier is oriented in an east/west direction, it need be

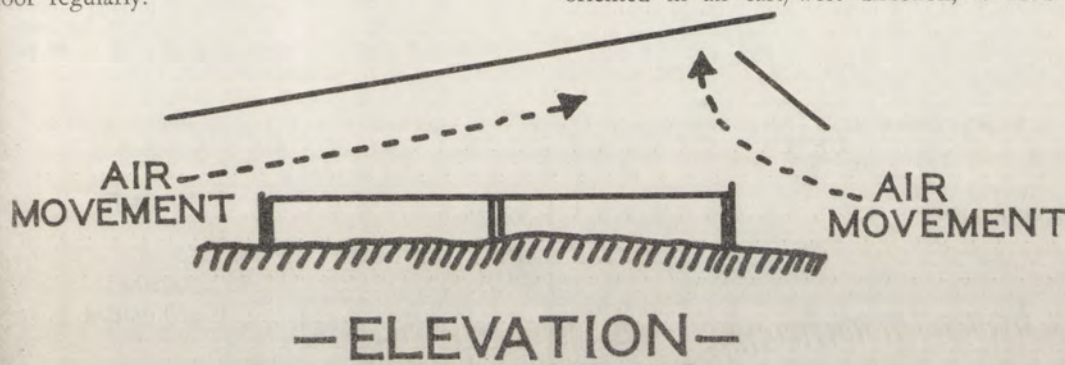


DIAGRAM VII.—Design of resting floor.

The standard fermenting boxes are three feet deep but should not be filled to a greater depth than two feet nine inches (half a ton D.B.E.) under normal circumstances.

5. Fermentary Building (covering the standard fermenting boxes).

Drainage requirements have been noted above. At Stage 3, a building 28 feet by 28 feet is required. Concrete the floor throughout. With Method "C" there will be no problem of corrosion of concrete.

Post height of the building will be determined by the site but should be high enough to give a close overlap of the roofs of the resting floors and the fermentary building. The roof must also be high enough to allow ample working room over the fermenting boxes and may be "skillion" or "gable". If gable, the ridge should be "jacked" a few inches. This will reduce corrosion. It is sufficient if the two-foot

only 10 to 12 feet away from the final fermenting boxes.

7. Building for Rotary Drier, Winnowing and Store

Site as closely as possible to the Sun/Hot-air platform drier without casting a shadow on it. The building should be at least 20 feet wide.

The length of the building, sufficient to house holding boxes, rotary drier and winnower, should be at least 30 feet. If the drive on the rotary drier is through a series of long belts and countershafts, the building will need to be longer. A more direct and compact type of drive saves space and is safer.

The building should be extended to provide a store for bagged cocoa. The length of this extension will depend on how often the grower can ship his dry beans. An extension of 15 feet to make the building 45 feet long will give comfortable storage space for more than 10 tons of bagged cocoa.

If there is a convenient fall from the platform drier to the top of the drum of the rotary drier, wall heights should be adjusted so that wall-ties, when suitably strengthened, can carry the loading platform above the rotary drier. If this is to be done, a "truss" roof will make for ease of working on the loading platform. In such a case, the holding boxes can be installed on the loading platform. They could even be placed on rails running between the platform drier and the rotary drier.

If there is a "lift-up" from the platform drier to the loading hoppers over the rotary drier, as will frequently happen, then either the rotary drier should be so sited in the building that wall-ties do not interfere with loading, or the building should have 12-foot posts so that any ties are well out of the way. Only low (eight-foot) walling is required on this building.

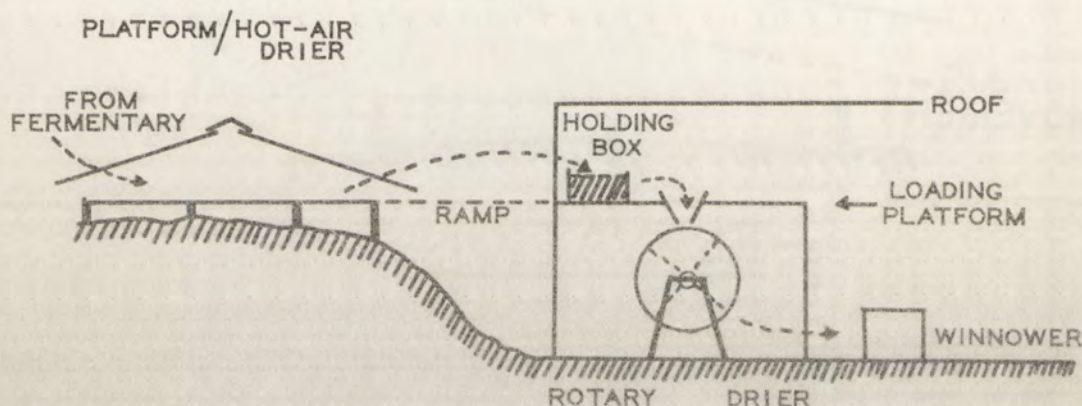


DIAGRAM VIII.—Split drying (ideal loading arrangement).

The ridge on this building should be "jacked" to prevent the accumulation of acid-laden air. The floor should be concrete throughout. In the "store" section, the concrete floor should be covered with open duck-boards so that bagged cocoa does not lie on damp concrete. Walls of the store should be unlined to avoid harbouring insects. A ceiling in this section of the building is desirable. When doors and windows are closed, it can then be effectively fumigated if insect infestation becomes apparent.

8. Labour Quarters

Suitable quarters for the specialist fermentary gang should be installed within calling distance of the fermentary.

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USEFUL FIGURES

- A cubic foot of wet beans usually weighs about 56 lb. on arrival at the fermentary.
- At the end of the resting phase in Method "C" a cubic foot of beans will weigh 46 to 48 lb.
- At the end of fermentation a cubic foot of beans weighs 42 to 44 lb.
- At the end of drying a cubic foot of beans weighs about 40 lb.
- A cubic foot of beans from the pod contains 7,000 beans (approximately). At the end of fermentation a cubic foot of beans contains 7,650 beans (approximately). At the end of drying a cubic foot of beans contains some 13,000 to 14,000 beans (rotary dried).
- It is evident from the above that during drying there is about 50 per cent. loss of both weight and volume as compared with wet fermented beans.
- Comparing wet *unfermented* beans with "dry" beans (six per cent. moisture), the recovery of dry beans after complete processing is usually 38 to 40 per cent.

60 cubic feet of wet beans yield 1,344 lb. dry beans,
55 cubic feet of wet beans yield 1,232 lb. dry beans.

Three batteries of standard fermenting boxes each filled to two feet nine inches to give 55 cubic feet will yield 3,696 lb. dry beans at each discharge—i.e., just more than a ton and a half. The equivalent in wet unfermented beans is 9,240 lb. When fermented, this quantity of beans will weigh 7,115 lb. and will occupy 156.75 cubic feet. As a rough guide, after 24 hours' drying on a platform/hot-air drier, the weight will be reduced to 5,330 lb. and the volume to about 120 to 125 cubic feet. When fully dry, the ton and a half of dry beans occupies a volume of 82 to 94 cubic feet.

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