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# MOISTURE AND OTHER QUALITY FACTORS OF COPRA

*by*

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## SUMMARY

Copra is essentially a food commodity and the entire subject of its inspection and analysis has assumed considerable importance in recent years.

Available factual background information pertinent to changes in the coconut kernel during development and germination of the drupe are discussed in some detail along with certain facts about copra and its characteristics. It has been deemed that these provide a somewhat sound and reliable basis for a discussion of the different factors which may be expected to affect the quality of copra.

As long as the mature coconut kernel always remains a fairly standard product there would appear to be no technical difficulties regarding the production of quality copra in all coconut growing countries. However, unsatisfactory methods of production are contingent on the lack of adequate monetary incentives for quality and market instability.

The factors that can be employed for the reliable assessment of copra quality include the evaluation of the commodity on (i) its physical characteristics and (ii) its analytical characteristics.

At the present time, the principal method by which purveyors of copra estimate its value is based on visual and tactile inspection. The method has the advantage of enabling large numbers of separate consignments to be marketed without the delay entailed by chemical analysis.

The three principal analytical characters which can be used for assessing copra quality are:—(i) Moisture content (ii) free Fatty acid content and (iii) Oil content. These quality factors of copra are considered in some detail in the paper and discussed in the context of commercial transactions and international trade.

## INTRODUCTION

In no department of analytical chemistry is greater difficulty experienced than in that which deals with the examination of natural food products. Of these food products perhaps none presents so much diversity in natural composition as do the oils, fats and fatty foods. This diversity of character combined with difficulty of resolution has made the examination of oils, fats and fatty foods both prolific of method and uncertain in result. Added to this, it should be pointed out that major difficulties are sometimes encountered in obtaining proper representative samples of the material for analysis. Each different substance has to be carefully considered and quite as much thought given to every stage of sampling as to the analysis. An obviously unrepresentative sample carelessly taken and analysed would doubtless be useless. In fact, nothing can be more absurd than for an analyst to apply all the skill and delicacy of careful analytical tests to a sample which does not represent the bulk of material of which it is required to know the composition.

Copra is essentially a food commodity and the entire subject of its inspection and analysis has assumed considerable importance in recent years. Based principally on studies carried out at the Coconut Research Institute (Ceylon), it is proposed to bring within the compass of this article as much available information as possible bearing on the different facts of the subject of copra quality. Before doing so, it is felt that a few facts about copra and its characteristics may be reviewed to advantage in order to afford a better understanding of the subject as a whole.

## CHANGES DURING DEVELOPMENT OF THE COCONUT

The intervals at which the coconut palm produces new flower spathes could vary a great deal. In the so called 'regular bearers' the number of spadices produced every year could range between 12 and 18. The usual tendency is for palms with smaller nuts to produce spathes at somewhat shorter intervals. Theoretically, every leaf axil is capable of producing an inflorescence, but due to various factors, some of these spathes abort during early development. A middle-aged palm would produce about 20 fronds and 14 spathes every year. In other words, about six spathes would abort prematurely.

In general, at any one time, if an average healthy palm is stripped into its components, it should be possible to isolate about 44 developmental stages of the floral branch. These would range between the initials of the primordial inflorescence (situated as a minute cone like protuberance in the axil of the fourth rudimentary leaf from the growing point) and the cluster of ripe green nuts as harvested. These 44 stages could be categorised into 3 groups as follows:—

i. *Stages* 1 *to* 10—spathes very rudimentary, undifferentiated and tender.

ii. *Stage* 11—inflorescence components differentiated.
*to* 29—spathe has just split open.

iii. *Stage* 30—the male phase.
*to* 44—ripe green cluster, with nuts containing the rudimentary embryo.

On the basis that a new spathe appears every 25 days, it would take the primordial inflorescence (Stage 1):—

(*a*) 1,100 days (approximately 3 years) to reach maturity (stage 44).

(*b*) 250 days (approximately 8 months) to reach stage 11, and

(*c*) 750 days (approximately 2 years) to reach stage 31.

Development stages 31 to 44 in the aforementioned classification are illustrated in (FIGURES 1 and 2).

The kernel first makes its appearance as a jelly like substance at stage 37 in the series. This would correspond to an age of about five months from the time of opening of the floral branch (stages 30/31). At stage 44 the kernel is fully formed and mature and is ideally suited for the preparation of quality copra. The age of the ripe drupe corresponding to stage 44 would be about twelve months from the time of opening of the spathe.

# Development of the Drupe (Progressive Stages)

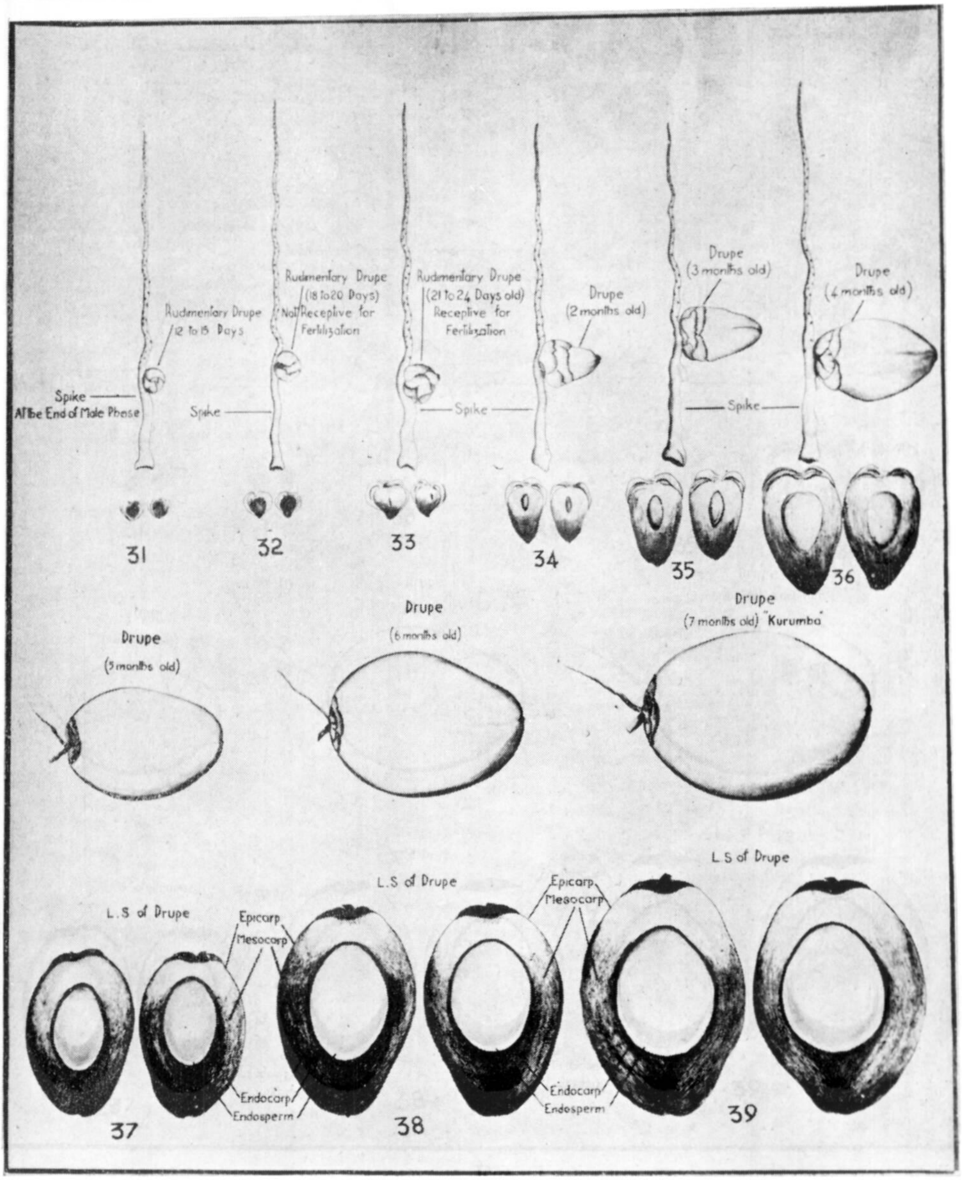


Fig. 1

Developmental Stages 31 to 39

# Development of the Drupe (Progressive Stages)

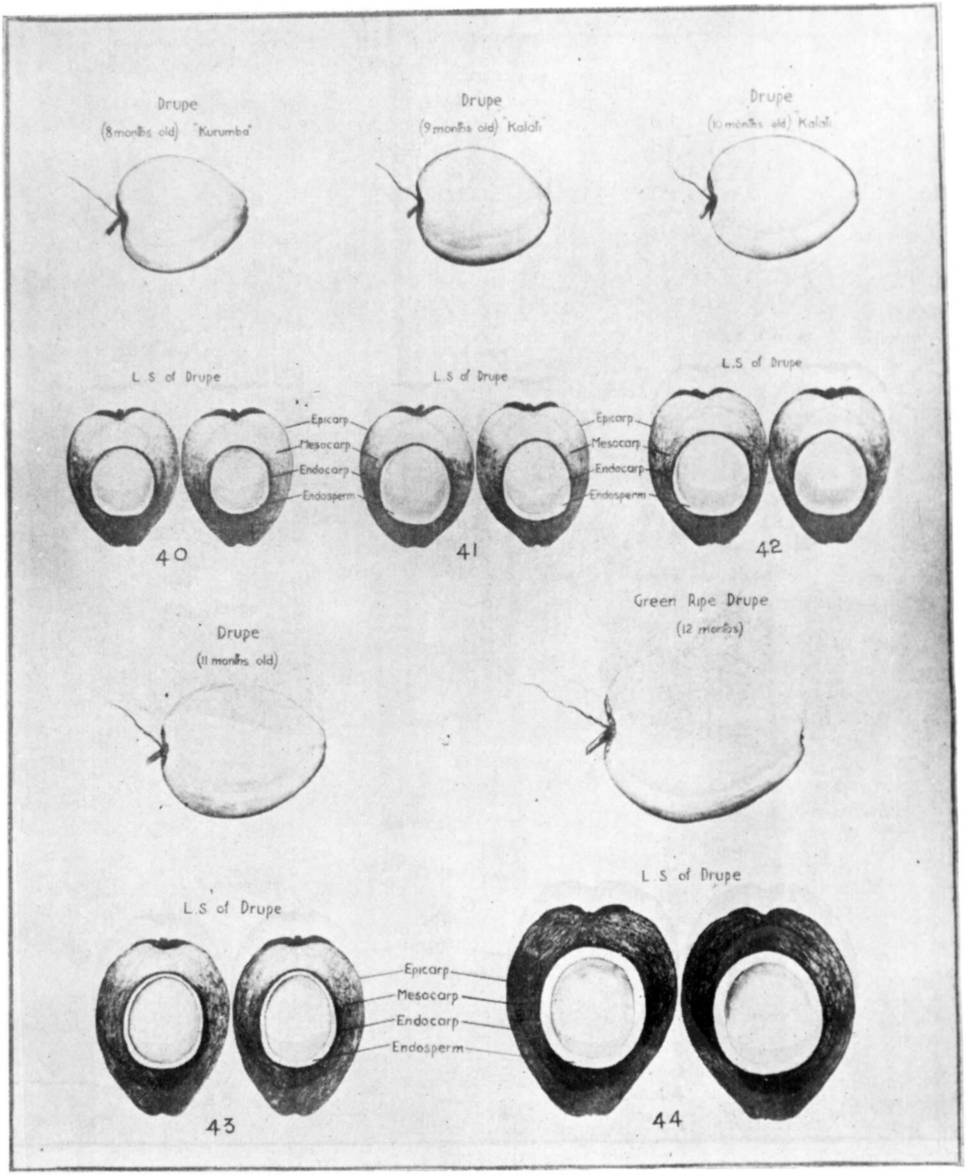


Fig. 2

Developmental Stages 40 to 44

The average oil and moisture contents in the kernel during the course of its progressive development between stages 37 and 44 are charted in (TABLE 1). Parallel data are also given showing the total wet and dry weights of kernel per drupe. These changes are illustrated graphically in (FIGURE 3).

## TABLE 1

**Changes in the Moisture and Oil Contents of the Coconut Kernel during Progressive Stages of Development**

| 1 | 2 | 3 | 4 | | 5 | | 6 |
|---|---|---|---|---|---|---|---|
| *STAGE* | *AGE (Months) from opening of spathe* | *% Total Moisture in Kernel* | *Weight of kernel/nut (grammes)* | | *% OIL* | | *Description* |
| | | | *WET* | *DRY* | *Wet basis* | *Dry basis* | |
| 31—36 | — | NO ENDOSPERM | | | | | No Pulp |
| 37 | 5 | 94.2 | 6.2 | 0.34 | 0.38 | 6.7 | Tender Kurumba |
| 38 | 6 | 92.4 | 27.0 | 2.1 | 1.25 | 16.4 | Kurumba |
| 39 | 7 | 90.8 | 58.0 | 5.4 | 3.6 | 38.7 | Mature Kurumba |
| 40 | 8 | 83.0 | 152.0 | 26.0 | 8.6 | 50.3 | Tender Kalati |
| 41 | 9 | 72.2 | 204.0 | 57.0 | 16.8 | 60.1 | Kalati |
| 42 | 10 | 63.4 | 239.0 | 88.0 | 24.4 | 66.7 | Mature Kalati |
| 43 | 11 | 45.9 | 284.0 | 154.0 | 38.3 | 70.8 | Nearly ripe drupe |
| 44 | 12 | 42.6 | 320.0 | 184.0 | 39.5 | 68.8 | RipeDrupe(Green) |

The results reveal the following interesting features:—

(*a*) That the moisture content steadily drops from about 94 per cent in the very tender gelatinous kernel to about 43 per cent in the ripe drupe.

(*b*) That the oil content (dry basis) unlike the moisture increases with the ripening of the fruit. The figures recorded show an increase from 6.7 per cent to 68.8 per cent. (*NOTE* The high value (70.8%) obtained in this study for stage 43 appears to be unusual).

(*c*) That there is a progressive increase in the deposition of dry matter in the kernel—the results showing an increase from 0.34 gramme to 184.0 grammes between stages 37 and 44.

## CHANGES IN MOISTURE, OIL CONTENT & ENDOSPERM WEIGHT DURING DEVELOPMENT

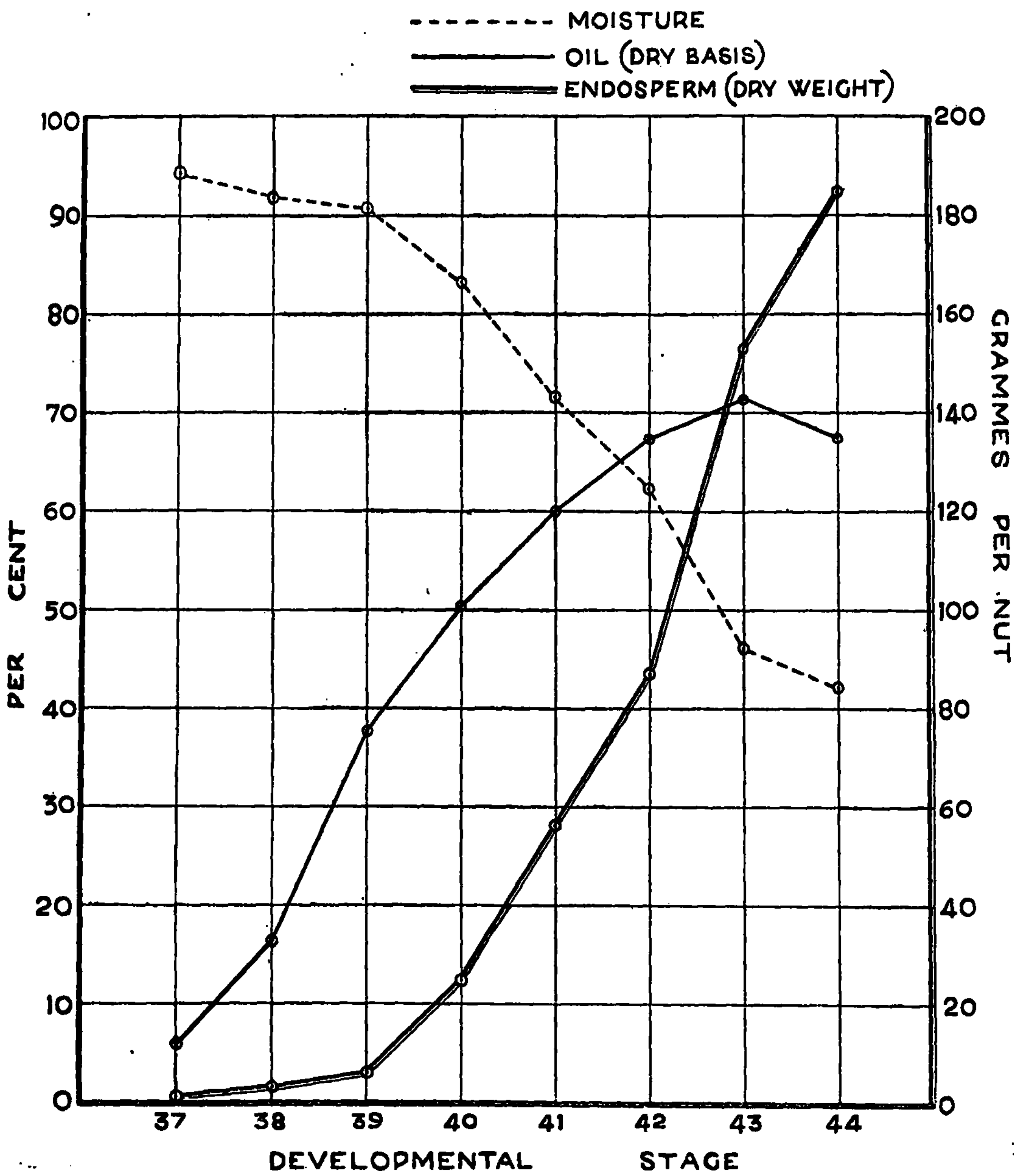


Fig. 3

Changes during development of the drupe

Having made the observation that the moisture content of the mature kernel is of the order of 43 per cent it might be useful to consider whether fluctuations or wide deviations from this figure do occur on storage or during seasoning. In this context various moisture studies have been made with a view to understanding better the changes that take place in the ripening coconut, the appraisal of the quality of copra and desiccated coconut and the mechanisms involved in their manufacture.

**TABLE 2**

**Moisture Content of the Mature Coconut Kernel WITH "Adventitious Moisture"**

| 1 | 2 | 3 | | |
|---|---|---|---|---|
| *SAMPLE* | *FALLEN NUTS* (*Dead ripe nuts naturally falling from the palm*) | *PICKED RIPE GREEN NUTS* | | |
| | | *Immediately on harvesting* | *After* 15 *days seasoning in the field* | *After* 30 *days seasoning in the field* |
| 1 | 46.67 | 47.14 | 44.91 | 44.36 |
| 2 | 46.59 | 46.41 | 44.53 | 44.26 |
| 3 | 46.92 | 46.83 | 43.81 | 42.99 |
| 4 | 46.31 | 46.37 | 45.18 | 43.44 |
| 5 | 46.48 | 47.73 | 43.95 | 43.58 |
| 6 | 46.02 | 46.96 | 44.04 | 43.16 |
| 7 | 47.83 | 46.94 | 43.93 | 44.22 |
| 8 | 47.29 | 47.81 | 44.53 | 43.23 |
| 9 | 47.30 | 47.96 | 43.98 | 43.09 |
| 10 | 47.31 | 48.07 | 44.93 | 43.37 |
| *MEAN* | 46.87 | 47.22 | 44.38 | 43.57 |
| *RANGE* | 46.02 *to* 47.83 | 46.37 *to* 48.07 | 43.81 *to* 45.18 | 42.99 *to* 44.36 |
| *S.D.* | 0.5563 | 0.6291 | 0.5007 | 0.5196 |
| *C.V.* (%) | 1.19 | 1.33 | 1.13 | 1.19 |
| *S.E.* | 0.1759 | 0.1989 | 0.1583 | 0.1643 |

*NOTE* The Kernels were sampled for analysis immediately on splitting the nuts.

S.D. — Standard Deviation
C.V. — Coefficient of Variation
S.E. — Standard Error

## TABLE 3

**Moisture Content of the Mature Coconut Kernel WITHOUT "Adventitious Moisture"**

| 1 | 2 | 3 | | |
|---|---|---|---|---|
| *SAMPLE* | *FALLEN NUTS* *Dead ripe nuts naturally falling from the palm* | *PICKED RIPE GREEN NUTS* | | |
| | | *Immediately on harvesting* | *After 15 days seasoning in the field* | *After 30 days seasoning in the field* |
| 1 | 43.93 | 44.44 | 43.99 | 45.92 |
| 2 | 41.98 | 44.48 | 43.34 | 44.98 |
| 3 | 42.91 | 43.50 | 44.00 | 45.76 |
| 4 | 43.87 | 44.54 | 42.55 | 44.58 |
| 5 | 43.48 | 43.66 | 43.80 | 43.58 |
| 6 | 43.22 | 43.18 | 43.46 | 44.88 |
| 7 | 43.52 | 43.74 | 44.51 | 43.74 |
| 8 | 43.62 | 43.88 | 44.11 | 42.70 |
| 9 | 44.38 | 43.17 | 43.50 | 42.50 |
| 10 | 43.62 | 43.65 | 43.04 | 43.73 |
| *MEAN* | 43.45 | 43.82 | 43.63 | 44.24 |
| *RANGE* | 41.98 *to* 44.38 | 43.17 *to* 44.54 | 42.55 *to* 44.51 | 42.50 *to* 45.92 |
| *S.D.* | 0.6532 | 0.5096 | 0.5720 | 1.1812 |
| *C.V.(%)* | 1.50 | 1.16 | 1.31 | 2.67 |
| *S.E.* | 0.21 | 0.16 | 0.18 | 0.37 |

*NOTE*—In order to estimate the moisture content of the Kernel *WITHOUT* "Adventitious Moisture", the half nuts were air-dried for 15 minutes after splitting and before drawing the samples for analysis.

S.D. — Standard Deviation
C.V. — Coefficient of Variation
S.E. — Standard Error

In the manufacture of desiccated coconut, the kernel (after paring) is to all intents and purposes disintegrated with 'adventitious moisture' picked up at the 'Washing' stage of processing. The kernel of the freshly opened coconut too, may be reckoned to contain adventitious moisture, owing to the fact that it is in direct contact with the 'liquid endosperm' within the water cavity. With these facts in mind, experiments were carried out with a view to obtaining reliable estimates of the moisture contents of the fresh mature kernel with and without adventitious moisture. Analytical data relevant to this subject are charted in (TABLES 2 and 3) above. For each category of nuts in the experiment, 250 drupes were taken and these were sampled and analysed carefully for moisture contents in ten lots of 25 each. This study was also partly extended to the kernel of the immature drupe during the 'kurumba' and 'kalati' stages. The results relevant to this are given in (TABLE 4). The figures are self explanatory.

## TABLE 4

### Moisture Contents of the Immature Coconut Kernel when it is associated WITH "Adventitious Moisture"

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| *Sample* | *Mature Kalati* | *Kalati* | *Mature Kurumba* | *Kurumba* |
| 1 | 66.23 | 68.11 | 85.99 | 93.80 |
| 2 | 64.71 | 68.22 | 85.79 | 92.81 |
| 3 | 64.70 | 66.50 | 84.34 | 91.87 |
| 4 | 66.50 | 67.85 | 85.10 | 93.12 |
| 5 | 65.80 | 67.20 | 84.65 | 92.43 |
| Mean | 65.59 | 67.58 | 85.17 | 92.81 |
| RANGE | 64.70 *to* 66.50 | 66.50 *to* 68.22 | 84.34 *to* 85.99 | 91.87 *to* 93.80 |
| S.D. | 0.8439 | 0.7201 | 0.7108 | 0.7253 |
| C.V.% | 1.29 | 1.07 | 0.83 | 0.78 |
| S.E. | 0.3774 | 0.3220 | 0.3179 | 0.3244 |

*NOTE.* The kernels were sampled for analysis immediately on splitting the nuts

S.D. — Standard Deviation
C.V. — Coefficient of Variation
S.E. — Standard Error

It will be seen from the data presented in Tables 2 and 3 that the figures summarised in (TABLE 5) represent the average moisture contents of the mature coconut kernel for the different categories of nuts examined in this study. Considering all categories of mature nuts it may now be inferred that 45.5% and 43.8% represent the overall moisture contents of the coconut kernel *WITH* and *WITHOUT* adventitious moisture respectively. In other words, the average adventitious moisture in the mature kernel may be reckoned to be of the order of 1.7% (ranging between 1.0% and 2.2%).

### TABLE 5

**Summary of Average Values for the Moisture Content of the Mature Coconut Kernel**

| 1 | 2 | | | |
|---|---|---|---|---|
| | *AVERAGE MOISTURE CONTENTS* | | | |
| *CATEGORY* | *WITH Adventitious Moisture* | | *WITHOUT Adventitious Moisture* | |
| | *Per cent* | *Range* | *Per cent* | *Range* |
| Fallen Nuts | 46.9 | 46.0 to 47.8 | 43.4 | 42.0 to 44.4 |
| Ripe Green Nuts (Fresh) | 47.2 | 46.4 to 48.1 | 43.8 | 43.2 to 44.5 |
| Ripe Green Nuts (After 15 days' seasoning) | 44.4 | 43.8 to 45.2 | 43.6 | 42.6 to 44.5 |
| Ripe Green Nuts (after 30 days' seasoning) | 43.6 | 43.0 to 44.4 | 44.2 | 42.5 to 45.9 |
| OVERALL AVERAGE | 45.5 | 43.0 to 48.1 | 43.8 | 42.0 to 45.9 |

## CHANGES DURING GERMINATION OF THE COCONUT

Having discussed the changes that take place in the kernel during the development of the coconut it might now be appropriate to consider the changes in moisture and oil content of the kernel during the progressive stages of germination itself. The observations on these changes are reakoned to be of some significance since certain commercial grades of copra invariably include the kernel from germinated coconuts. Further, these observed changes would also have a bearing on the subject of quality standards.

The analytical data presented in (TABLE 6) represent the changes that take place in the kernel during progressive stages of germination up to a period of 24 months from planting. These changes are expressed graphically in (FIGURE 4).

## TABLE 6

**Changes in the moisture and oil content of the Coconut Endosperm during Progressive Stages of Germination**

| 1 | | 2 | 3 | | 4 | 5 | |
|---|---|---|---|---|---|---|---|
| *Number of weeks in Nursery* | | *% Moisture in Kernel* | *Weight of kernel per Nut (grammes)* | | *Wt. of oil per nut (grammes)* | *% OIL* | |
| | | | *Wet* | *Dry* | | *Wet basis* | *Dry basis* |
| | nil | 43.7 | 345 | 194 | 133.3 | 38.7 | 68.7 |
| | 2 | 43.2 | 346 | 197 | 134.2 | 38.7 | 68.1 |
| ( 1 month) | 4 | 45.1 | 351 | 193 | 131.8 | 37.5 | 68.3 |
| | 6 | 43.3 | 339 | 192 | 134.4 | 39.7 | 70.0 |
| ( 2 months) | 8 | 42.1 | 350 | 203 | 139.9 | 39.9 | 68.9 |
| | 10 | 42.3 | 343 | 198 | 138.8 | 40.4 | 70.1 |
| ( 3 months) | 12 | 42.9 | 344 | 196 | 135.8 | 39.6 | 69.3 |
| | 14 | 42.6 | 346 | 199 | 139.3 | 40.2 | 70.0 |
| ( 4 months) | 16 | 42.2 | 336 | 194 | 137.0 | 40.8 | 70.6 |
| | 18 | 41.5 | 324 | 190 | 133.8 | 41.2 | 70.4 |
| ( 5 months) | 20 | 41.9 | 303 | 176 | 128.3 | 42.4 | 72.9 |
| | 22 | 40.1 | 289 | 173 | 127.7 | 44.2 | 73.8 |
| ( 6 months) | 24 | 40.0 | 281 | 169 | 124.9 | 44.3 | 73.9 |
| | 26 | 39.2 | 271 | 165 | 123.6 | 45.5 | 74.9 |
| ( 7 months) | 28 | 37.5 | 242 | 151 | 115.1 | 47.6 | 76.2 |
| (7.5 months) | 30 | 33.4 | 216 | 144 | 110.4 | 51.1 | 76.7 |
| (9.5 months) | 38 | 28.6 | 123 | 88 | 67.2 | 54.5 | 76.4 |
| (12 months) | 48 | 29.2 | 92 | 65 | 49.9 | 54.4 | 76.8 |
| (15 months) | 60 | 28.0 | 72 | 52 | 39.1 | 54.1 | 75.2 |
| (18 months) | 72 | 33.1 | 53 | 38 | 27.9 | 49.1 | 73.4 |
| (21 months) | 84 | 37.4 | 48 | 34 | 22.4 | 41.2 | 65.8 |
| (24 months) | 96 | 42.3 | 33 | 24 | 15.3 | 36.8 | 63.8 |
| MEAN (2 years) | | 39.1 | 248 | 147 | 105.0 | 43.7 | 71.6 |
| RANGE | | 28.0 to 45.1 | 33 to 351 | 24 to 203 | 15.3 to 139.9 | 36.8 to 54.5 | 63.8 to 76.8 |

The distinctive features of the results may be summarised as follows:—

(*a*) There is a decided tendency for a drop in the moisture content of the kernel during germination. This becomes particularly marked after 20 weeks from planting, from which stage onwards there is a steady fall in moisture from 41.9% to 28.0% after 60 weeks. The increase thereafter is not reckoned to be significant as it is probably due to contamination with soil water in the nursery.

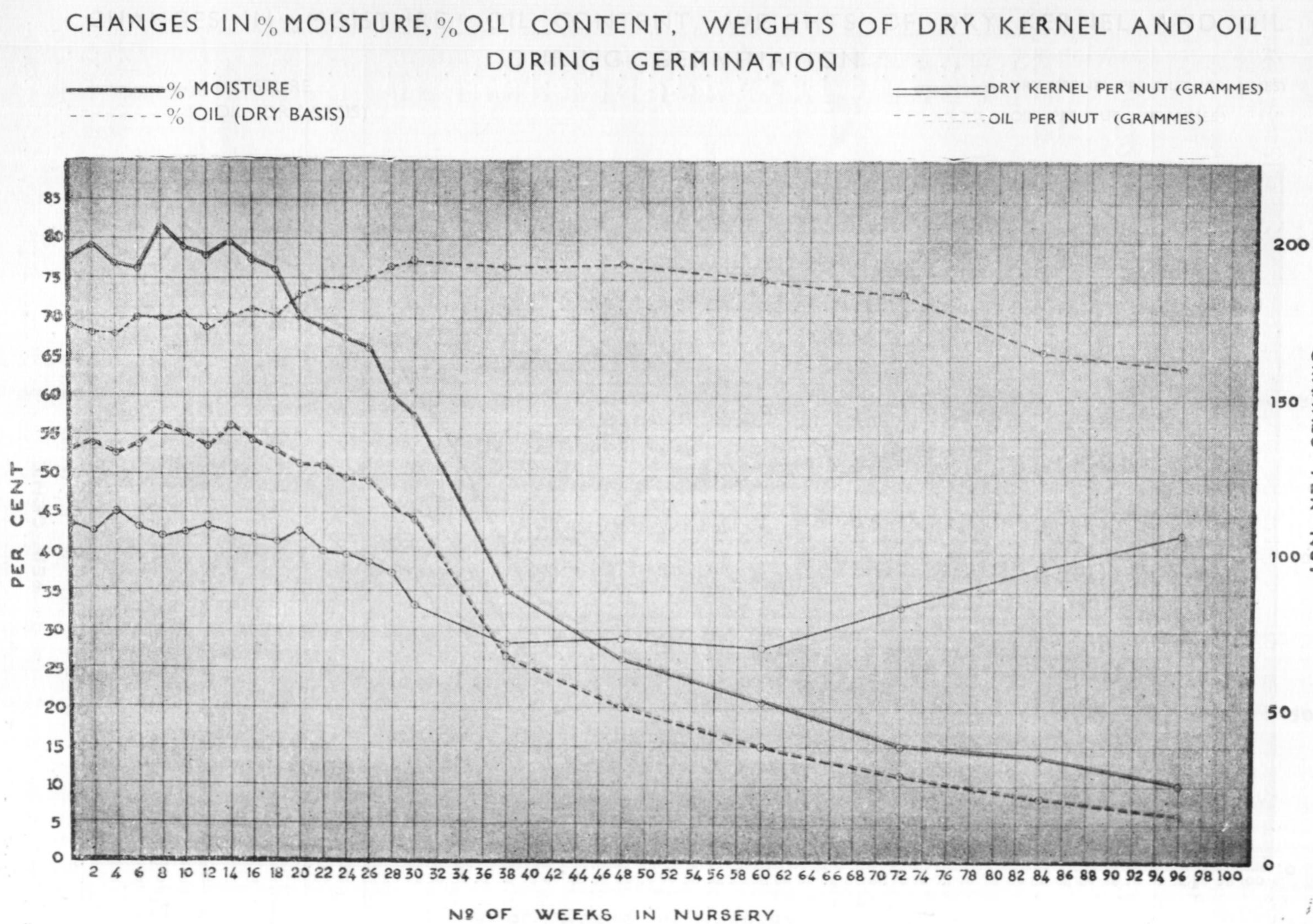


Fig. 4

Changes during Germination of the Drupe

(*b*) Unlike moisture, the tendency for changes in the oil content is definitely in the reverse direction. It will be seen that after 20 weeks this becomes very marked—the oil percentage almost steadily rising from 72.9% to 76.8% (dry basis) after 12 months.

(*c*) Regarding the question of actual oil recoveries per nut it will be seen from column 4, that there is a persistent drop after 18 weeks from 133.8 grammes to 15.3 grammes.

(*d*) Though the oil contents are high when expressed as a percentage, it will be seen that these high values actually correspond to lower recoveries of oil per nut. The inference can therefore be drawn that from the commercial point of view *on a weight basis* the low grade copra prepared from well germinated coconuts will doubtless yield more oil on expression. Though this will be of value to the oil miller, yet it should be remembered that the quality of oil and also the poonac recovered is inferior and would entail refinement losses. From the point of view of production economics however there is no significance or advantage in preparing copra from germinated coconuts, because the quantity of oil recovered per nut is below average. That this is so will be evident when we consider the fact that the average oil recovery per nut during the first 18 weeks of planting is 136 grammes and for the period 20-96 weeks is only 79 grammes. (computed from Table 6, Column 4).

It should be pertinent and interesting at this stage to attempt an explanation for the foregoing observations made on the changes that take place in the kernel during germination.

The figures presented in (TABLE 7) demonstrate conclusively that there are to be found in the coconut kernel definite oil and moisture gradients when it is sliced tangentially, parallel to the testa or brown integument.

**TABLE 7**

**Oil and Moisture gradients in the Coconut Endosperm**

| 1 | 2 | 3 | |
|---|---|---|---|
| *REGION* | *% MOISTURE* | *% OIL* | |
| | | *Wet basis* | *Dry basis* |
| T | 29.1 | 44.2 | 62.4 |
| RT | 32.9 | 50.6 | 75.4 |
| IR | 44.1 | 37.9 | 67.8 |
| RW | 59.3 | 22.9 | 56.3 |

T = Testa IR = Intermediate Region
RT = Region near Testa RW = Region near water Cavity

For the experiment, the fresh kernels from ungerminated coconuts alone were used. These were split into cups (half nuts) in the usual way and 1/8 " radial strips were taken from each cup by making longitudinal cuts. Each of these strips was then sliced parallel to the testa so that besides the parings three sections of approximately equal thickness were obtained from the white meat. The corresponding sections from each strip were then bulked, and analysed for moisture and oil content.

The results show that the section least rich in oil (56.3%) is on the inside nearest the water cavity. The section richest in oil (75.4%) is nearest the testa, and the intermediate section fits in between with an oil content of 67.8%. The testa itself contains 62.4% oil. It will be seen that the moisture gradient is in the reverse direction. These features are clearly illustrated in (FIGURE 5).

With a knowledge of these facts it is indeed easy to understand the changes that have been observed in the kernel during germination. In germination it would appear that the inside tissues least rich in oil progressively break down as the haustorium (or "apple") develops, leaving the layers which are richer in oil. That this is plausible will be seen from the fact that the oil content of 76.7% recorded for the very thin kernel wafer from drupes that have been in the nursery for 7½ months is not far different from 75.4% the oil content registered for the region of the kernel nearest the testa.

The explanation for the drop in moisture content of the kernel with the progress of germination, is similarly provided by the fact that the tissues on the inside which breakdown first are richer in moisture (59.3%) than the residual layers nearer the testa (29.1%).

## CHARACTERISTICS OF CEYLON ESTATE COPRA

The literature contains recorded oil peicentages for copra from various producing countries. These figures have been found to be very variable ranging between 57 to 75 per cent. The sources of these figures may be said to vary in reliability and in many cases could not be regarded as being truly representative. It is felt that the very high figures have been recorded on deteriorated low grade samples of copra where due to mould action the inside layers of the kernel have been destroyed. The unusually low figures have probably been recorded for copra derived from immature coconuts. It can be said however that apart from such causes definite variations do seem to occur but no definite conclusions can be drawn from the available data.

Without doubt Ceylon copra could be considered superior to that produced in most other countries. In general practice, copra produced on estates in this country is sorted into three grades which are categorised as numbers 1, 2 and 3. It should be informative at this stage to consider the general quality and analytical characteristics of these 3 grades.

With the aforementioned object of obtaining information of a positive and reliable nature samples of Nos. 1, 2 and 3 copra from seven estates in different parts of the island were drawn

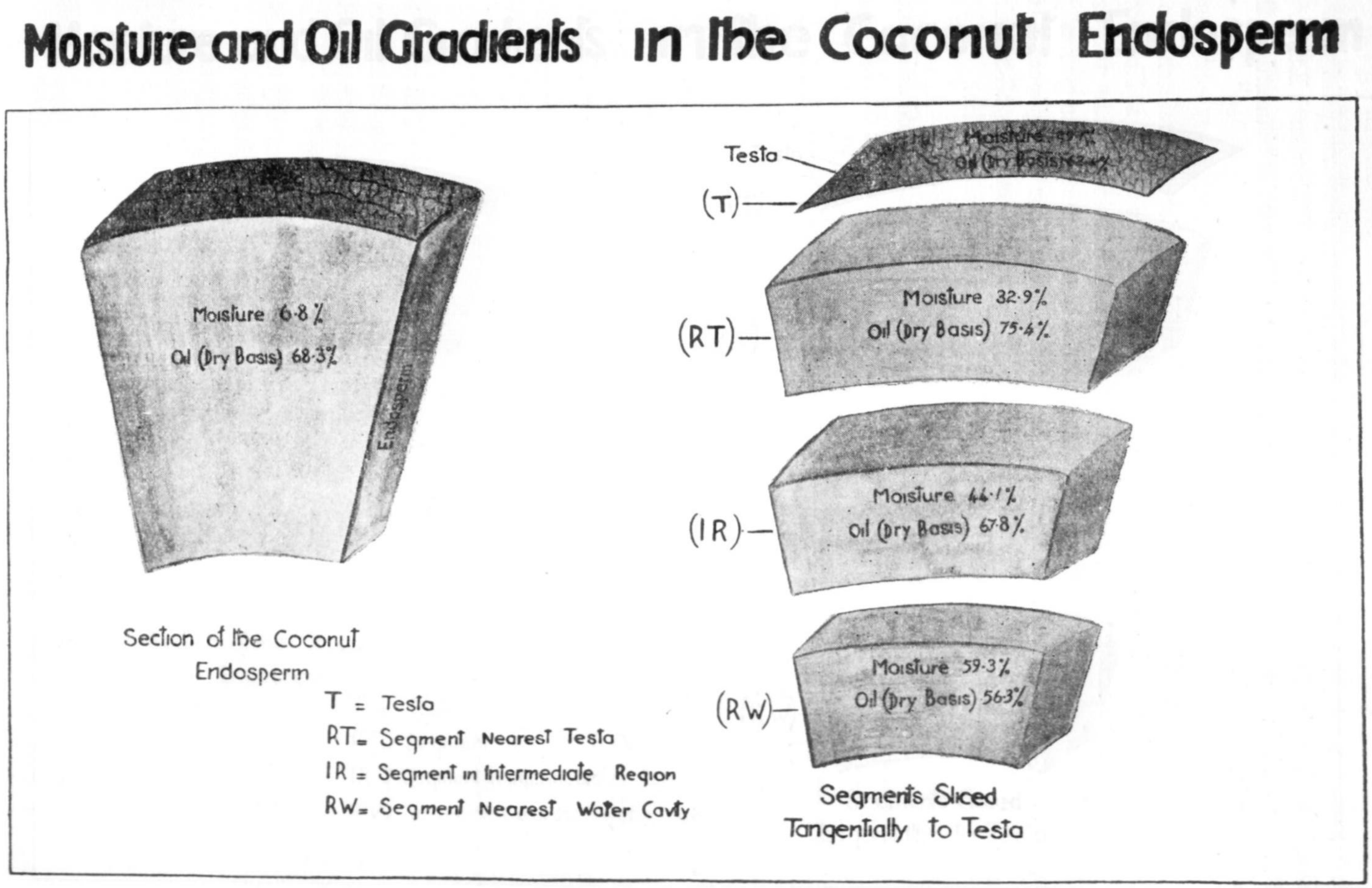


Fig. 5

Moisture and Oil Gradients in the Coconut Endosperm at regular intervals and a comprehensive set of analytical determinations carried out. The situations of the seven estates were as follows: two in the Western Province (Mirigama and Kalutara district), three in the North-Western Province (Puttalam, Chilaw and Kurunegala districts) and one each in the Eastern and Southern Provinces. The results obtained in these studies are summarised in (TABLES 8 to 11).

Before we proceed to consider the results, it should be useful to make some reference to the manner in which copra is sorted and graded on estates. As a rule, what is classed at No. 1 copra would include halves from mature, well seasoned and ungerminated nuts that are well dried, of good colour and free from dirt, stains and burnt marks. The halves would also generally be of good shape and appearance. From the bulk of copra from the kiln, after curing is completed, such No. 1 copra is first sorted out. The remainder is usually given a further firing after which a little more No. 1 may be separated and the rest is sorted into No. 2 and No. 3 grades.

No. 2 copra would be as well dried as No. 1, but may be somewhat discoloured as by smoke and other stains. It will generally include halves from somewhat immature nuts or slightly germinated nuts. Into No. 3 go badly discoloured halves, soft leathery halves from very immature nuts and thin cups with shrivelled surfaces derived from germinated nuts. The very black charred and perishing pieces which are sometimes mixed with No. 3 copra should in proper estate practice be classed separately as "refuse copra".

Apart from the efficiency of the kiln and the skill of the curers, factors influencing the proportion of the inferior grades are droughts, which lead to immature nut-fall, wet weather during curing and delay in curing leading to increased germinations. As there appears to be considerable variation in estate sorting practice, the percentage distribution of Nos. 1, 2 and 3 would also doubtless be contingent on the particular grading system employed. The overall average sorting figures typical for the whole year on Bandirippuwa Estate have been found to be: No. 1 Copra, 94.5, No. 2, 4.5 and No. 3, 0.7 per cent.

Regarding the analytical results for Estate No. 1 copra it may be said at once that no definite variation in the percentage of oil content of the copra with the situation of the estate can be established from these results. Even the maximum difference observed (that between estate Nos. 3 and 6—Table 8), does not appear to be statistically significant. These figures indicate that the value 68.3% (dry basis) is a reasonably accurate one for the average dry weight oil percentage of No. 1 Ceylon Estate Copra. The results summarised in Table 11 gives confirmation of this, showing that 38 out of 52 samples (i.e. 73% of the total) fall in the two groups 67-68 and 68-69 per cent. These studies have further revealed that no relation of oil content to the time of year (when the nuts were harvested) could be established. The overall average moisture content of the samples examined will be seen to be 6.8%.

Regarding the free fatty acid content of the extracted oils from estate No. 1 copra, the analytical figures in Table V column 7, show that the average is only 0.06%, indicating that the copra samples as analysed were fresh and undeteriorated. The interesting fact that coconut oil is one of the least variable of the commercial fats is indicated by the little variation shown in the iodine and saponification values.

## TABLE 8

**Analysis of No. 1 Estate Copra**

| 1 | 2 | 3 | 4 | | | 5 | | | 6 | | | 7 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *No. of Estate* | *Province* | *No. of Samples* | *% Moisture* | | | *% OIL (wet weight)* | | | *% OIL (dry weight)* | | | *% OIL (average values for)* | | |
| | | | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Iodine Value* | *Saponific-ation value* | *F.f.a. (ex-tracted oil)* |
| 1 | W.P. | 6 | 7.4 | 5.1 | 6.5 | 65.5 | 62.8 | 64.1 | 69.2 | 67.8 | 68.5 | 8.2 | 258.6 | 0.07 |
| 2 | E.P. | 6 | 7.4 | 5.8 | 6.8 | 64.8 | 63.2 | 63.9 | 69.5 | 67.9 | 68.6 | 8.0 | 256.8 | 0.07 |
| 3 | N.W.P. | 6 | 8.9 | 7.4 | 8.2 | 63.8 | 61.3 | 62.3 | 69.0 | 66.5 | 67.8 | 8.2 | 256.9 | 0.06 |
| 4 | W.P. | 12 | 8.1 | 5.6 | 7.1 | 65.0 | 61.7 | 63.0 | 69.1 | 66.5 | 67.8 | 8.2 | 259.4 | 0.06 |
| 5 | N.W.P. | 6 | 6.8 | 6.0 | 6.4 | 65.0 | 63.1 | 64.3 | 69.3 | 67.5 | 68.6 | 8.0 | 259.8 | 0.05 |
| 6 | S.P. | 6 | 7.9 | 5.6 | 6.4 | 65.4 | 63.4 | 64.4 | 69.7 | 68.1 | 68.8 | 8.3 | 261.1 | 0.05 |
| 7 | N.W.P. | 6 | 7.2 | 5.2 | 6.1 | 65.3 | 62.9 | 64.3 | 69.0 | 67.6 | 68.5 | 8.2 | 260.4 | 0.05 |
| Miscellaneous | | 4 | 7.9 | 4.5 | 6.3 | 65.3 | 62.0 | 63.9 | 69.2 | 66.7 | 68.2 | 8.0 | 258.9 | 0.15 |
| Total | | 52 | 8.9 | 4.5 | 6.8 | 65.5 | 61.3 | 63.7 | 69.7 | 66.5 | 68.3 | 8.16 | 259.1 | 0.06 |

(*NOTE:* under Miscellaneous are 4 samples as follows: 2 random samples from estates not included in the original seven and 2 samples taken from bulk in Colombo Stores)

## TABLE 9
### Analysis of No. 2 Estate Copra

| 1 | 2 | 3 | 4 | | | 5 | | | 6 | | | 7 | | | 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *No. of Estate* | *Province* | *No. of Samples* | *% MOISTURE* | | | *% OIL (wet weight)* | | | *% OIL (dry weight)* | | | *Free Fatty Acid (extracted oil)* | | | *Free Fatty Acid (pressed oil)* | | |
| | | | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* |
| 3 | N.W.P. | 6 | 8.2 | 4.2 | 6.3 | 68.1 | 63.6 | 65.7 | 71.1 | 69.0 | 70.2 | 0.66 | 0.04 | 0.22 | 0.86 | 0.04 | 0.32 |
| 5 | N.W.P. | 6 | 8.1 | 4.3 | 6.1 | 68.9 | 62.5 | 66.1 | 72.6 | 67.7 | 70.3 | 0.40 | 0.06 | 0.16 | 0.40 | 0.04 | 0.22 |
| 6 | S.P. | 6 | 6.9 | 5.2 | 6.0 | 67.7 | 65.2 | 67.0 | 72.5 | 70.0 | 71.1 | 0.52 | 0.02 | 0.22 | 1.76 | 0.04 | 0.49 |
| 7 | N.W.P. | 6 | 8.5 | 2.5 | 6.9 | 66.7 | 63.4 | 64.7 | 70.4 | 68.9 | 69.5 | 0.23 | 0.04 | 0.18 | 0.58 | 0.04 | 0.22 |
| Total | | 24 | 8.5 | 4.2 | 6.4 | 68.9 | 62.5 | 65.9 | 72.6 | 67.7 | 70.3 | 0.66 | 0.02 | 0.20 | 1.76 | 0.04 | 0.31 |

## TABLE 10
### Analysis of No. 3 Estate Copra

| 1 | 2 | 3 | 4 | | | 5 | | | 6 | | | 7 | | | 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *No. of Estate* | *Province* | *No. of Samples* | *% MOISTURE* | | | *% OIL (wet weight)* | | | *% OIL (dry weight)* | | | *Free Fatty Acid (extracted oil)* | | | *Free Fatty Acid (pressed oil)* | | |
| | | | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* | *Max.* | *Min.* | *Av.* |
| 3 | N.W.P. | 6 | 8.9 | 4.3 | 6.6 | 67.5 | 61.9 | 63.9 | 70.5 | 66.7 | 68.5 | 0.95 | 0.12 | 0.39 | 0.97 | 0.28 | 0.55 |
| 5 | N.W.P. | 6 | 7.4 | 4.0 | 6.2 | 66.4 | 61.7 | 64.5 | 70.6 | 66.2 | 68.8 | 0.65 | 0.18 | 0.41 | 1.05 | 0.15 | 0.65 |
| 6 | S.P. | 6 | 7.1 | 4.8 | 6.0 | 69.2 | 64.7 | 67.1 | 72.7 | 69.3 | 71.4 | 0.57 | 0.19 | 0.39 | 1.33 | 0.24 | 0.76 |
| 7 | N.W.P. | 6 | 9.4 | 5.4 | 7.1 | 66.4 | 61.7 | 63.4 | 70.2 | 66.2 | 68.2 | 0.39 | 0.08 | 0.28 | 1.17 | 0.18 | 0.46 |
| Total | | 24 | 9.4 | 4.0 | 6.5 | 69.2 | 61.7 | 64.7 | 72.7 | 66.2 | 69.2 | 0.95 | 0.08 | 0.37 | 1.33 | 0.18 | 0.60 |

## TABLE 11

**Distribution of Moisture and Oil Contents (No. 1 Estate Copra)**

| *% MOISTURE* | | *% OIL (Dry basis)* | |
|---|---|---|---|
| *Group* | *No. of Determinations* | *Group* | *No. of Determinations* |
| 4 to 5% | 1 | 62—63% | 0 |
| 5 to 6% | 11 | 63—64% | 0 |
| 6 to 7% | 21 | 64—65% | 0 |
| 7 to 8% | 14 | 65—66% | 0 |
| 8 to 9% | 5 | 66—67% | 4 |
| 9 to 10% | 0 | 67—68% | 14 |
| — | — | 68—69% | 24 |
| — | — | 69—70% | 10 |
| Total | 52 | Total | 52 |

In general it may be said that most Ceylon Estate No. 1 copra is satisfactory in all but appearance, which can be improved somewhat by preventing smoking. There seems little need in most cases to recommend more stringent drying.

With regard to the analytical results on Estate Copra (nos. 2 and 3), it is not altogether surprising that the oil percentage of the inferior grades are on the whole higher than that of No. 1 copra. More than one factor may contribute to this. For instance, it has been observed that long continued drying tends to decompose slightly and decrease the weight of the constituents of copra other than oil without affecting the oil itself. The percentage of oil in the finished copra is thus increased. It has already been mentioned that No. 2 and No. 3 copra is usually dried longer than the first selected No. 1. Then of course the fact that there is an oil gradient in the kernel (which has been demonstrated) would also tend to give higher oil percentage as the inside tissues are removed by mould or bacterial action.

That, in the present study, the average oil content of No. 3 copra (69.2%) is somewhat lower than that of No. 2 (70.3%) is probably to be explained by the inclusion in this grade, of copra from very immature nuts. The slightly immature kernels which go into No. 2 have oil contents not very different from that of ripe nuts, but the oil content of very immature kernels has already been shown to be much less. Any increase in the oil content due to the factors described in the preceding paragraph is thus offset to some degree.

That all the samples of copra received for this study have been well dried will be clear from Tables 8 to 10. We have already noted an average of 6.8 per cent moisture for 52 samples of No. 1 copra. Tables 9 and 10 record a range of 4.2-8.5 (average 6.4) for 24 samples of No. 2, and a range of 4.0-9.5 (average 6.5) for 24 samples of No. 3.

Regarding the free fatty acid content of the extracted oils from the three grades, it has been noted already that for the samples of fresh No. 1 copra very few contained over 0.1 per cent, the average being only 0.06 per cent. The acidities of the oils from No. 2 and No. 3 copra are naturally higher but not unduly so. It will be seen that the averages are 0.20 and 0.37 per cent for the No. 2 and No. 3 grades respectively. It is both significant and interesting that the corresponding figures obtained on samples of the pressed oil are higher, averaging 0.31 and 0.60 per cent respectively for the two grades. It is proposed to revert to this point later in the context of copra sampling.

It is apparent from the results obtained that there can be little objection to the use of No. 2 and No. 3 grades for local milling on the grounds of oil content or quality. Their physical nature should however be regarded as an objection to their use for milling, because rubberiness is regarded as a fault because it tends to choke machinery and impede efficient pressing. In local practice however No. 2 copra and even No. 3 is bulked in certain proportions with No. 1 for purposes of crushing. The inferior grades are of course undesirable for overseas shipment because they are more liable to deterioration by moulds.

## COPRA FROM VARIETIES GROWN IN CEYLON

Apart from the size and maturity of the fruit it is reasonable to expect that the quantity of copra and oil in a coconut would also be influenced to some extent by other factors such as varietal (and genetic) differences, climate (in its widest sense), soil conditions and perhaps fertilizer regime.

The *typica* or tall coconut palm which is cultivated on a plantation scale represents the variety that is propagated essentially for commercial purposes. Besides this there are also other varieties and forms which are grown to a limited extent in the island. The economic possibilities of evolving hybrids (with high oil contents in the kernel) by selective breeding is no doubt an interesting speculation and is considered a subject well worth investigation. It is deemed appropriate therefore at this stage, that any information so far accumulated on the oil content of the different available types should be compared with those that have been established for the *tall* palm. These figures are reviewed in (TABLE 12) below. It should be mentioned that only fresh samples of copra were used in this study so that they were uncomplicated by the changes accompanying deterioration or germination.

It will at once be apparent from the analytical results that the dwarf green (69.9%)—*nana* variety, Gon thambili (69.2%)—a form of the *typica* variety, and Bodiri (69.6%)—also a form of the *typica* variety, are the only ones if at all which have given somewhat higher figures than the commercial tall palm for oil content. As variations could be very wide it is proposed to check up on further samples whether these three types do in fact give consistently higher figures of significance to warrant botanical investigations.

## TABLE 12

### (Oil content of the varieties and forms of Coconut grown in Ceylon)

| 1 | 2 | 3 | 4 | | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| *Sample* | *Variety or Form* | *% Mois-ture* | *% OIL* | | *No. of Nuts* | *Weight Copra (lbs.)* | *Out-turn Nuts/ candy* | *Copra Quality* |
| | | | *Wet basis* | *Dry basis* | | | | |
| 1 | Tall palm (variety-*Typica*) | 6.8 | 63.7 | 68.3 | 2,600 | 1133.96 | 1,284 | Uniformly good. |
| 2 | Dwarf Green (variety-*Nana*) | 6.2 | 65.6 | **69.9** | 102 | 24.00 | 2,380 | Fair (not Uniform) |
| 3 | Dwarf Red (a form of *Nana*) | 6.8 | 60.8 | 65.2 | 90 | 17.25 | 2,922 | Inferior |
| 4 | Dwarf Yellow (a form of *Nana*) | 7.1 | 60.8 | 65.5 | 100 | 24.75 | 2,263 | Inferior |
| 5 | King Coconut (variety) | 7.4 | 60.8 | 65.6 | 100 | 31.25 | 1,792 | Fair |
| 6 | Ran Thambili (a form of *Typica*) | 7.5 | 63.3 | 68.5 | 19 | 9.25 | 1,150 | Good |
| 7 | Gon Thambili (a form of *Typica*) | 6.6 | 64.6 | **59.2** | 55 | 28.00 | 1,100 | Good |
| 8 | Bodiri (a form of *Typica*) | 7.2 | 64.6 | **69.6** | 20 | 2.25 | 4,978 | Inferior |
| 9 | San Ramon (a form of *Typica*) | 8.0 | 60.4 | 65.6 | 66 | 42.50 | 870 | Good |
| 10 | Kamandala (Giant) (a form of *Typica*) | 7.2 | 62.8 | 67.6 | 45 | 37.50 | 672 | Good |

(1 candy = 560 pounds)

Regarding the possible effects of climatic and edaphic factors on the oil content of the coconut kernel, there would appear to be some corroborative evidence to support this view. For instance, the average oil percentage (dry weight) for Malayan estate copra (typica variety) found by Georgi[1] is 65.6; whereas for Estate copra it is 68.3. Cooke[2] quotes analyses of 3 parcels of No. 1 Ceylon copra as follows: (*a*) 70.13 (*b*) 68.72 and (*c*) 68.2 per cent oil (dry weight) and other similar figures are on record. Fritsch[3] quotes for a sample of Ceylon copra 68.6 per cent. Further, an authoritative handbook on oils and fats[4] gives the following average figures:—

| | |
|---|---|
| Straits copra | 65.0 to 66.5 |
| Indonesia | 65.8 to 67.5 |
| Ceylon | 67.0 to 69.5 |

It can be regarded as established, therefore that there is a difference of from 2-3 per cent oil percentage in favour of Ceylon copra. Further, since Cooke found a difference of about 1 per cent between copras from Ceylon and Malayan nuts respectively, both cured under the same conditions, the difference cannot be altogether explained by adducing the slower drying technique practised in Ceylon. The one per cent difference must therefore be due to some unexplained fundamental difference between the two countries, probably a resultant of the climatic environment.

Regarding fertilizer regime, the final criterion of yield in manurial and other experiments on the coconut palm is actually the quantity of oil obtained per acre. In practice however this would be an unwieldy procedure and the presentation of results on the basis of copra yields has to suffice. It is at the same time important to know whether manurial applications to coconut palms have any pronounced influence on the oil content of the copra produced.

To examine the above questions, records of copra yields per acre have been kept at the Coconut Research Institute and also moisture and oil determinations carried out on samples of copra from selected plots of the Soil Chemist's duplicated (3 ×3 ×3) factorial experiment on differential NPK manuring. The results have shown significant increases in the yield of copra (and thus oil) per acre over the years for different levels of potash manuring. For the complete results reference should be made to the Institute's published Annual Reports, but typical data are reproduced in (TABLE 13).

**TABLE 13**

**Soil Chemist's NPK Experiment—Yields of Copra**

| *YEAR* | *Pounds Copra per Acre* | |
|---|---|---|
| | $K_1$—$K_0$ | $K_2$—$K_0$ |
| 1936 | 26 | 50 |
| 1937 | 47 | 80 |
| 1938 | 47 | 114 |
| 1939 | 28 | 120 * |
| 1940 | 190 * | 240 ** |
| 1941 | 122 | 196 ** |
| 1942 | 352 ** | 196 ** |
| 1943 | 300 ** | 407 ** |
| 1944 | 362 ** | 546 ** |
| 1945 | 329 ** | 422 ** |
| 1946 | 312 ** | 447 ** |
| 1947 | 382 ** | 512 ** |
| 1948 | 442 ** | 582 ** |
| 1949 | 401 ** | 546 ** |
| 1950 | 543 ** | 711 ** |
| 1951 | 664 ** | 846 ** |
| 1952 | 547 ** | 799 ** |
| Total for 17 years | 5,094 | 7,097 |
| Mean/annum | 294 | 418 |

* Significant at P .05 ** Significant at P .01

Regarding the question of oil content there has been no indication whatever that the differential manurial treatments are reflected in the oil percentages of the copra samples. In fact it is surprising that the variation has been very small, the coefficient of variation recorded for the 96 samples examined being only 1.2 per cent.

Patel[5] quotes oil percentages of copra from 17 plots receiving different manurial treatments in a trial carried out in Madras, which he states appear to show that *all* treatments increased the oil content. His oil percentage figures which average 55.0 per cent were obtained by crushing the copra in a country oil mill. The recovery by this means would of course be very low and variable and the question of obtaining results sufficiently consistent for experimental purposes is reckoned an impossibility.

The experiments carried out on this subject at the Coconut Research Institute have only shown that during the second year after application, different fertilizer treatments to coconut palms, did not affect the oil content of the copra. The possibility however cannot be excluded that significant differences of oil content might begin to show themselves after the palms have been differentially treated for a longer period. It is hoped to be able to check up on this point in the near future.

## THE CEYLON COPRA KILN

In view of the fact that Ceylon copra is still recognised as the world's best commercial copra, it is felt that it would be appropriate to consider the drying stages and working procedure of the standard Ceylon Copra kiln.

The Ceylon Dryer which is fully described in Leaflet 15 published by the Coconut Research Institute (Ceylon) is a simple structure consisting essentially of a fire pit, a copra grill or platform, a corrugated iron roof fitted with a jak roof and covered working verandah. It has well known merits being easily adaptable for use on large plantations as well as small village holdings. The drying procedure embodies adequate safeguards to minimise the production of inferior copra.

In drying practice, the halves of the split nuts are laid carefully face upwards on the barbecue for one day's sun-drying. In the late afternoon they are collected and put on the platform of the kiln to a depth not exceeding 12 inches. After this the operator arranges the shells in the fire pit in parallel double rows, each shell being nested between continguous shells. The curing process takes about five days with about eight to nine firings. Details of the working programme during the five days curing have been carefully outlined in the leaflet.

It might be interesting at this stage to consider typical drying time curves obtained with the standard Ceylon dryer when following the operational schedule outlined in the leaflet. (TABLE 14) below gives typical moisture figures obtained during successive stages when the copra is cured in the form of (*a*) out kernels and (*b*) half nuts. The data are graphically represented in (FIGURE 6)

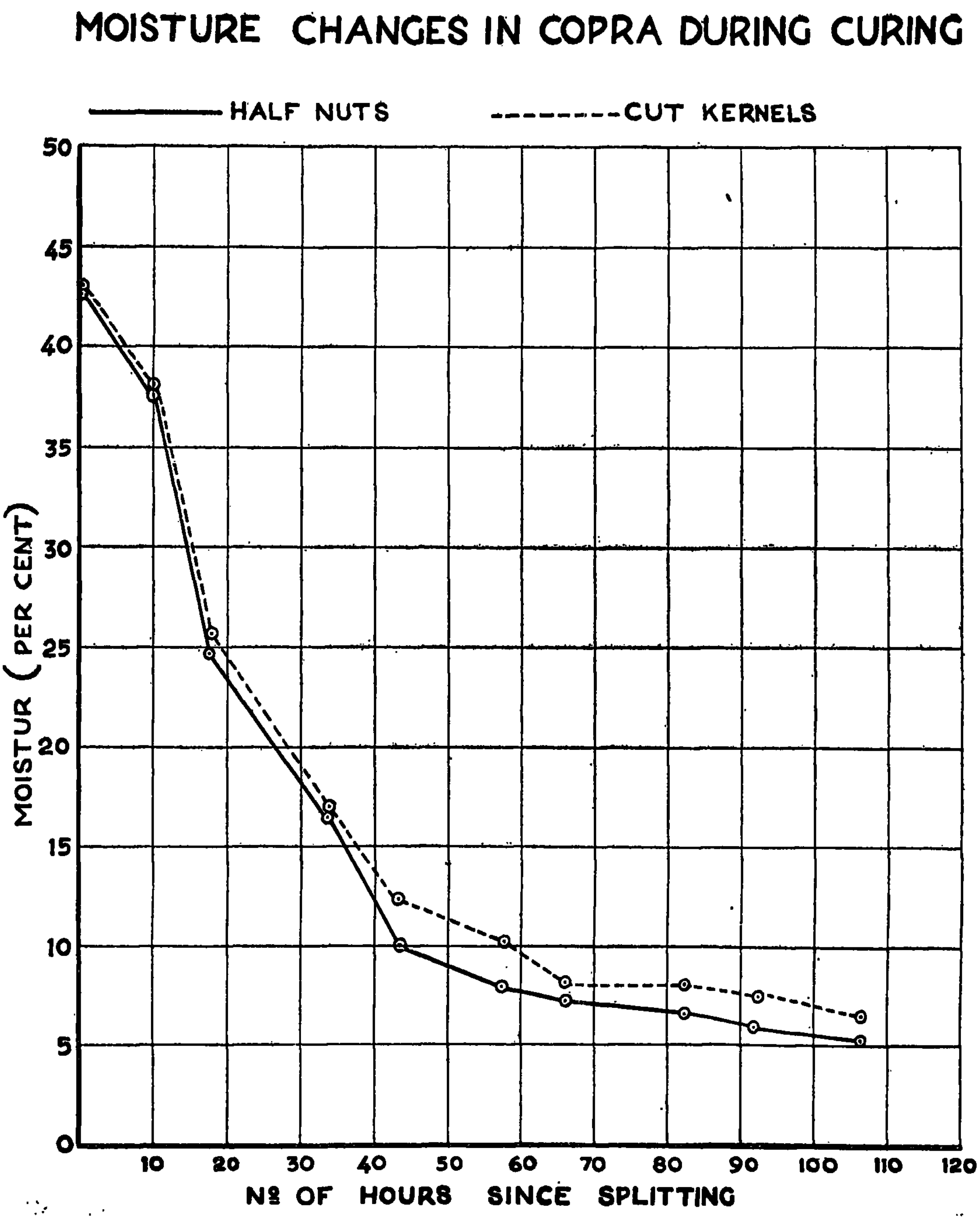


Fig. 6

Progressive Moisture Changes in Copra during Curing

It has been shown already that the moisture content of the fresh coconut kernel may be expected to reasonably average 43.8%. It is generally reckoned that for optimum keeping qualities copra should be dried down to between 5 and 6 per cent moisture content. For the present purpose an average optimum of 5.5% may be adopted. This would mean that for practical purposes the essential principle involved in copra manufacture is the reduction of the moisture content from the original 43.8 per cent to 5.5%. In other words, 87.4 per cent of the total moisture in the original kernel would have to be removed. To accomplish this a host of drying systems have been evolved the world over in the different coconut growing countries. For a knowledge of these, reference could be made to two recent publications (6) and (7) which deal fairly exhaustively with the subject.

Though a discussion of the merits and demerits of the Ceylon Dryer itself is outside the ambit of this paper, yet we could compare and contrast the salient features of the experimental results which have been presented in (TABLE 14) with some of the general findings and recommendations made in the FAO publication.[6]

**TABLE 14**

**(Moisture changes in Copra during curing procedure in Ceylon Kiln)**

| 1 | 2 | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|
| *Stage* | *No. of hours since splitting* | *% Moisture* | | *Total moisture loss since splitting* | | *Total moisture loss as % of original* | |
| | | *Cut Kernels* | *Half Nuts* | *Cut kernels* | *Half nuts* | *Cut kernels* | *Half nuts* |
| On splitting | nil | 43.5 | 43.3 | nil | nil | nil | nil |
| After Sundrying | 10 | 38.0 | 37.8 | 5.5 | 5.5 | 12.6 | 12.7 |
| ,, 1st firing | 19 | 25.7 | 24.8 | 17.8 | 18.5 | 40.9 | 42.7 |
| ,, 2nd firing | 34 | 17.1 | 16.4 | 26.4 | 26.9 | 60.7 | 62.1 |
| ,, 3rd firing | 43 | 11.9 | 10.0 | 31.6 | 33.3 | 72.6 | 76.9 |
| ,, 4th firing | 58 | 10.1 | 8.0 | 33.4 | 35.3 | 76.8 | 81.5 |
| ,, 5th firing | 67 | 8.5 | 7.4 | 35.0 | 35.9 | 80.5 | 82.9 |
| ,, 6th firing | 82 | 8.4 | 6.5 | 35.1 | 36.8 | 80.7 | 85.0 |
| ,, 7th firing | 91 | 7.8 | 6.0 | 35.7 | 37.3 | 82.1 | 86.1 |
| ,, 8th firing | 106 | 6.6 | 5.4 | 36.9 | 37.9 | 84.8 | 87.5 |

On page 36 of this publication the statement is made that, "Eight hours of continuous sun-drying with low atmospheric humidity and the sky free from cloud or mist, are sufficient to drive off half the moisture which has to be removed before the product is commercially dry, i.e. containing 6 to 7 per cent moisture". Obviously under climatic conditions prevailing in Ceylon (especially in the N.W.P.) this does not appear to obtain. It will be seen from the results that only about 12 per cent of the total moisture is lost during 10 hours of initial sundrying.

Regarding essential drying principles the following have been epitomised on page 40 of the publication under reference:—

(1) The moisture content has to be reduced from 50-55 % to 35 per cent preferably within 24 hours.

(2) During the second 24 hours the moisture content should be reduced to about 20 %.

(3) In the next 24 hours the moisture content should be reduced to 5 or 6 per cent.

It will be seen at once from Table 14, column 3 that for the Ceylon Dryer the above requirements are more than fulfilled during the first 48 hours which may be regarded as the critical period of drying. Where the requirement is a reduction of the moisture content to 35 % within 24 hours the results show that after 19 hours the moisture has already dropped to 25-26 %. Again, when the requirement for 48 hours is a reduction to 20 %, the results show that in 43 hours the moisture is down to 10-12 %. During the next 24 hours however it will be seen that the rate of dryage is definitely slow in terms of the requirement. It would take at least 96 hours for the moisture to be reduced to 5-6 % in the Ceylon kiln as against the limit to 72 hours fixed. In the writer's opinion, from the point of view of copra quality the slower drying towards the end (in the Ceylon procedure) is a desirable feature. When the bulk of the moisture in the kernel has been expelled, overheating would definitely tend to caramelize the sugars with resultant discolouration, decomposition and also hardening of the meat.

It has already been pointed out that the principal virtue in the Ceylon kiln is its adaptability to both small and large scale processing. It can be said that there should be no difficulty in producing fairly uniform high grade copra with it, provided the standard operational procedure is rigidly adhered to. The question however of obtaining drying time curves approximately those illustrated on page 39 of the above publication (without loss of quality of the finished product) can be ruled out as a virtual impossibility. Curves such as the ones illustrated, where the moisture in the kernel drops from 50 to 5 per cent in eleven hours and even one hour can only be accomplished where artificial means are employed for the control of temperature and air speed. Further, these methods require special plant involving expensive fabrication, and special conditions for operation, which consequently limit their application.

Relevant to the observations made on the Ceylon kiln, it is noteworthy that under precisely the same conditions it is definitely more advantageous and economical to cure copra in the form of half nuts instead of cut or broken pieces. Apart from the rate of dryage itself, it will be seen from the results that for the cut kernels, even after eight firings the moisture content is yet 6.6 per cent as against 5.4 % for the cups.

It has been found that as many as two extra firings may be required to reduce the moisture content further to 5.5 % when curing pieces. The fact that cut kernels deteriorate quicker than cups is a widely acknowledged fact. In transport too, broken pieces disentegrate further creating more and more "fines" and undesirable dust, which not only increase the acidity of the product but are also wasteful in handling. In general it can be stated that it is seldom that broken or cut kernels make the best copra.

## GENERAL DISCUSSION

The available factual background information, pertinent to the title of this article, which has been reviewed above, may be regarded as a somewhat sound and reliable basis for a discussion of the different factors which may be expected to affect the quality of copra. As long as the mature coconut kernel always remains a fairly standard product there can be no reason why quality copra cannot be produced in all coconut growing countries. The actual problem however is that in the absence of definite monetary or price incentives with assurance of market stability no amount of propaganda or advice can induce producers to change their unsatisfactory methods of production.

### (*a*) Factors that can be used for the reliable assessment of Copra quality.

The factors which can be employed for the reliable assessment of copra quality may be classified into two groups as follows:—

(i) Evaluation of the commodity on its physical characteristics.
(ii) Evaluation on its analytical characteristics.

The old trade custom was to judge copra purely on its appearances. Any chemical analyses to reflect the quality of shipments had no accepted trade recognition and were employed in commercial transactions simply to emphasise or indentify disputed points of quality that were or were not indicated by appearances. In recent years however copra analyses have been gainfully used to some extent by crushers both as an advance guide before deliveries reached plants and for factory control purposes.

(i) *Physical characteristics.* It may be said that even at the present time the principal method by which purveyors of copra estimate its value is entirely based on visual and tactile inspection. Visitors to the London Copra Association or the Ceylon Coconut Board Sales Room, bodies whose sole function is arbitration between buyer and seller, will not find any apparatus for chemical analysis but merely long benches or racks on which the samples are exposed to the scrutiny of the judges.

Though this method may appear unreliable it should be pointed out that it is based upon the experience of the valuer who appreciates the relationship between external characters and the analytical characteristics. This relationship is based on the fact that good appearance is associated with careful preparation with low moisture and free fatty acid content and good oil content. The method has the principal advantage of enabling large numbers of separate consignments to be marketed without the delay entailed by chemical analysis.

In general, the physical properties that may be taken into consideration for the valuation of copra by appearance may be summarised as follows:—

| Physical Property | Good Copra |
|---|---|
| 1. Colour | The colour should be as white as possible. |
| 2. Size and thickness | The copra should be thick and should not contain too great a proportion of small pieces. |
| 3. Cleanliness | The copra should be free from extraneous matter. |
| 4. Dryness | The copra should have a pearly lustre with biscuit hardness and be free from moulds. |
| 5. Condition | The copra should be round thick and smooth. |
| 6. Smell | Characteristic and sweet. |

(ii) *Analytical Characteristics.* The three principal analytical characters which can be used for assessing copra quality are:—

(*a*) Moisture content.
(*b*) Free Fatty acid content and
(*c*) Oil Content.

*Moisture content.* Of the three above mentioned analytical characters 'moisture content' may be regarded as *the* most important factor which determines copra quality. Nothing else could in fact compensate for inadequate dryage. Even in the physical method of inspection scrutineers base their principal judgment on the basis of dryness which men of experience could accurately estimate by the feel of the hands.

It is too well known that the keeping qualities of copra depend upon its moisture content. Walker[8] has recommended that copra should be dried to 5 per cent and long storage avoided. Brill, Parker and Yates[9] give a figure of 6 per cent. Regarding the action of moulds Lava[10] has reported that the "critical moulding moisture content" under a relative humidity of 81 per cent and about 28-30° C would be 8 per cent. The inference could of course be made that under conditions of *higher* humidity the moulds would appear at a lower moisture content. Passmore[11] records observations on copra stored in a London riverside warehouse from March to October, 1930 under an average relative humidity of 84.6 per cent. The copra remained mould free during this period and he has concluded that copra once dried to 6-7 per cent moisture content would not re-absorb sufficient moisture under ordinary conditions to support even a superficial mould growth.

The question of moisture re-absorption of copra under damp conditions is rather an important one and could be appropriately considered here. It can be said that if the temperature is assumed to be constant, there will be a point of equilibrium between the moisture of the copra and that in the atmosphere at every degree of relative humidity. Passmore (loc. cit.) regards this as about 5 per cent under English conditions. This means that copra drier than this will absorb moisture from the air until its content reaches 5 per cent, and copra wetter will dry out to 5 per cent. Cooke (loc. cit.) records that in Malaya the moisture content of good copra freely exposed to the air fluctuated between 3.5 and 8.0 per cent. In the low country of Ceylon (unpublished) observations of a similar nature show a range of 5.2 to 7.9 per cent and the interesting point is that sun-dried copra which can be regarded as having been dried to equilibrium point, an average moisture content of 7.8 per cent has been found.

Taking into consideration all the recorded observations on the moisture content of copra it would be a reasonable recommendation that *good copra* should be dried down to a moisture content between 5 and 6 per cent, in order to ensure maximum keeping qualities. Under humid conditions however where there is likelihood of moisture re-absorption there is little to gain by such stringent dryage. A range of 6-7 per cent may be reckoned adequate under such conditions, when serious deterioration will not take place provided the copra is stored in well ventilated dry stores at an even temperature.

*Free Fatty Acid.* In the widest possible sense "rancidity" may be defined simply as a deterioration in odour and flavour which develops in fats on keeping. Generally, as the rancidity of a fat increases its free fatty acid percentage also rises. Though they do not run exactly parallel the F.f.a. content may be regarded as a measure of rancidity. The method is simple and in suitable cases sufficiently sensitive to detect the progress of deterioration even before "off" flavour or visible mould growth appears.

The figures given in the present study for the f.f.a. contents of the various grades of estate copra demonstrate that they are of positive comparative value. It will be seen that the respective acid values of the extracted oils do in fact correspond to different degrees of deterioration and rancidity. There can be no doubt that this is indeed one of the valuable analytical factors which can be used to advantage in assessing the quality of copra. It should however be mentioned that if it is to be used in commercial transactions then the ultimate value of the system would depend entirely on the representative character of the samples taken and their preparation and analysis. Further, it is also important to adhere closely to proven methods that have been demonstrated to give results comparable with practical crushing. This is indeed a crucial factor, because when there is a lack of thoroughness and accuracy all else that follows in a transaction could fail in its purpose and will not provide a trustworthy basis for settlement. *Oil content.* On the basis of the preliminary survey, it could be safely concluded that the producer would have little or no control over the oil content of his copra. In fact, it has been shown that no regular variations in the oil content or composition have been detected with the time of plucking or with the situation of the estate.

Since the actual oil percentage in a sample of copra as received will obviously depend on its moisture content, for comparative purposes oil percentages should always be calculated on the dry weight, i.e. as percentages of the moisture free copra. This is valuable both from the point of view of making ready comparisons of relative oil contents, and also in fixing standards for the oil content (without moisture complications). As the moisture content of commercial copra is so very variable the importance of expressing oil contents on a dry basis is demonstrated in (TABLE 15) below. The example taken for the illustration is a typical sample of estate copra containing 68.3 per cent of oil on a dry basis. A range of calculated figures is given showing how the oil content in this sample would change for graduated increases in the moisture from 0.5 to 10.0%.

## TABLE 15

**Changes in the oil percentage of a sample of Copra with increase of Moisture**

| *% Moisture* | *% Oil (Dry Wt.)* | *% Decrease in oil* |
|---|---|---|
| 0.0 | 68.300 | |
| 0.5 | 67.958 | |
| 1.0 | 67.617 | 0.683 |
| 1.5 | 67.276 | |
| 2.0 | 66.934 | 0.683 |
| 2.5 | 66.592 | |
| 3.0 | 66.251 | 0.683 |
| 3.5 | 65.909 | |
| 4.0 | 65.568 | 0.683 |
| 4.5 | 65.226 | |
| 5.0 | 64.885 | 0.683 |
| 5.5 | 64.544 | |
| 6.0 | 64.202 | 0.683 |
| 6.5 | 63.860 | |
| 7.0 | 63.519 | 0.683 |
| 7.5 | 63.177 | |
| 8.0 | 6 .836 | 0.683 |
| 8.5 | 62.494 | |
| 9.0 | 62.153 | 0.683 |
| 9.5 | 61.811 | |
| 10.0 | 61.470 | 0.683 |

The figures eloquently show that for every rise of one per cent in the moisture the oil content would decrease by 0.683%. The implications of this in commercial transactions should therefore be obvious, because on a *weight basis* the actual oil recovery would be contingent on the exact moisture content of the consignment. To take an extreme example, suppose 2 lots of copra (100 pounds each containing 68.3% oil on a dry basis) are bought at the same price ignoring the moisture factor. If we assume that in actuality one lot had 5% moisture and the other 15% moisture then the quantities of oil that could be recovered from the two lots would be found on calculation to be:—

| *Lot* | *Quantity (lbs.)* | *Moisture (lbs.)* | *Dry matter (lbs.)* | *Oil (lbs.)* |
|---|---|---|---|---|
| 1 | 100 | 5 | 95 | 64.88 |
| 2 | 100 | 15 | 85 | 58.05 |
| | | | Difference | 6.83 |

Since the transaction is done purely on a weight basis, this would imply that besides paying partly for water, the actual oil recovery from lot 2 would be 6.83 pounds less from lot 1, or 153 pounds less for every ton of copra handled. The example further shows the importance of specifying the actual moisture content wherever the oil content is expressed on the sample as received (i.e. on a wet basis), so that the figures if required could be computed on a dry basis.

The oil content of the kernel can certainly be used as a factor for the assessment of copra quality, but in view of the findings described in the preliminary survey, high percentages need not necessarily signify better quality. If this point is overlooked the position may arise where the inferior grades will pass the standard but not the superior ones. This point is reckoned to be worthy of note.

### (*b*) Quality standards that can be reasonably enforced in commercial transactions.

As already mentioned copra is generally bought and sold—not on analysis of sample—but on a standard based on appearance. Though this may be adequate for the very superior grades it is the writer's opinion that a consideration of both physical and analytical factors is the only reliable basis for the assessment of quality in commercial transactions. Even when this is done the subject can yet be difficult because it interlocks with all the problems associated with grading and sampling.

Though separate standards may have been laid down for each producing country there is no accepted general standard. This of course is considered a virtual impossibility because copra is such a highly variable product. The formulation and enforcement of strict standards (embracing both physical and analytical characters) would only become a practical proposition as long as definite grades have been recognised and established.

### (*c*) Need for grading system with grade standards.

Whether or not international standards are agreed upon and introduced, as a first step it would appear that a unified system of copra grading for the various exporting countries would be a desirable feature. It is felt that if the system is to work with any degree of efficiency, rigid standards would have to be coupled with adequate incentives for the production of the higher grades. So long as the grading systems and standards in the various exporting countries are not comparable the problem of evolving acceptable international standards would indeed be made more difficult.

In the context of legislative enactments, it has been the experience in some Crown Colonies that in the absence of adequate price premia and incentives, attempts to improve the quality of exported copra by legislation have not proved very effective.

The system of grading copra according to the country of origin and to description of grade cannot be regarded as an altogether satisfactory method, as it hinges on the difficult problem of the producer and exporter working in close collaboration. The terms used in international trade to arbitrarily define quality standards are given in publication[6] which are reproduced hereunder in (TABLES 16 and 17) for ready reference.

**TABLE 16**

| *Standard Copra Grades in order of Market Value* | | |
|---|---|---|
| F. m. g. w. s.<br>F. m. s.<br>F. m. s. Standard<br>F. m. s. Trade<br>F. m.<br>F. m. Hot air dried.<br>F. m. mixed.<br>F. m. kiln dried, and so on. | | |
| F. m. g. w. s. | — | Fair, merchantable, good, white, sundried. |
| F. m. s. | — | Fair, merchantable, sun-dried. |
| F. m. | — | Fair, merchantable (not necessarily sundried, usually kiln-dried). |
| F. m. mixed | — | Fair, merchantable, mixed (i.e. sundried and kiln dried proportionately but not necessarily 50/50). |

**TABLE—17**

**Definitions of several Grades of Copra (not internationally accepted)**

| Description | Definition |
|---|---|
| Perfect, super grade | Smooth, hard clean, snow white, free from all extraneous and defective matter. |
| High grade | Smooth, hard, clean, pale grey to dull white, with no discoloured or bad pieces. |
| F.m.s., made on improved kilns or on estates | Commercially white, dry copra, containing between 5 and 50% of somewhat smoky or slightly discoloured pieces. |
| Mixed, ordinary smoke dried | Underdried copra of uncertain and irregular quality. |
| F. m. | A blend of dry mixed and dry low grade copra with no hard white pieces but much soft and rubbery copra. |
| Low grade | Underdried copra consisting entirely of burnt, discoloured, oversmoked, putrid, insect ridden, rubbery and/or soft glutinous pieces with much torn and broken material. |

Though the grading and testing of copra on the basis of predetermined qualifications and standards would not necessarily ensure its arrival at the port of discharge in the same condition, yet the buyer could always expect a high degree of uniformity within the grades. It can only be repeated for emphasis, that the evolution of a unified and efficient grading/sorting system on the basis of clearly defined standards (to be applied within all exporting countries) could be regarded as *sine-qua-non* if standardization of copra grades in the larger sphere of international trade is to be accomplished in the future.

### (*d*) Prerequisite conditions that would ensure production of high quality copra.

In broad outline the conditions that should be observed to ensure the production to high quality copra could be epitomised as follows:—

- (i) *Careful Harvesting* avoiding under-ripe (immature) and over-ripe (germinated) coconuts.
- (ii) *Seasoning*. Whenever picked green ripe nuts are used they should be seasoned on the field for a period of 3-4 weeks.
- (iii) *Careful Pretreatment*. During husking and splitting operations in particular where contamination with extraneous matter could occur, or sliming overnight of cracked nuts.
- (iv) Careful processing in efficient kilns.

For full details reference could be made to Leaflet No. 25 published by the Coconut Research Institute on this subject. (FIGURES 7 and 8) illustrate some types of dry and deteriorated copra.

### (*e*) Copra sampling.

Emphasis has already been placed in this article on the importance of careful and representative sampling of a commodity like copra. It has also been pointed out that unless this is ensured all other analytical operations could be just futile.

In view of the multifarious drying treatments and the numerous concomitant factors of processing, copra could be a highly variable product of very heterogeneous quality, so much so that in a sample representing hundreds of tons it may be difficult to find even two pieces exactly alike. Wherever damage is most pronounced free fatty acids and colour of the oil would tend to be highest. Further broken pieces and "fines" which are highest in free fatty acids and lowest in oil content would have to be uniformly incorporated in the sample to be analysed to ensure consistent and reliable results. Naturally in commercial methods any sampling technique employed would have to overcome these problems if dependable results are to be obtained. Since the National Institute of Oilseed Products (N.I.O.P.) has evolved a suitable method for the commercial sampling of copra, this subject has not been considered in this article. It should however be mentioned that commercial samples are taken by professional samplers who by long experience acquire skill in the art.

The question of sampling copra in the laboratory is a comparatively simple process and a satisfactory method giving concordant results on duplicates has been worked out and applied at the Coconut Research Institute.



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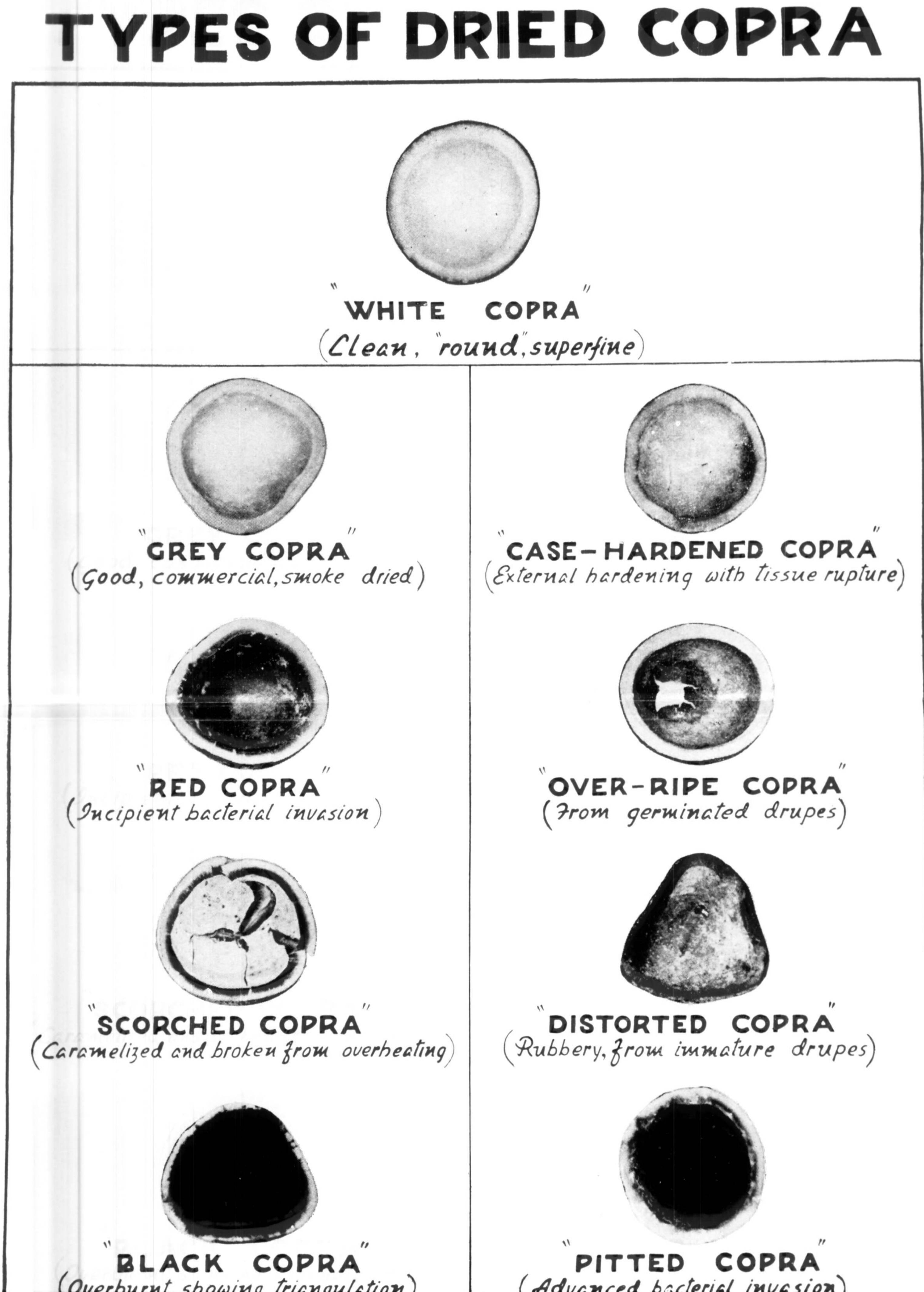


Fig. 7

Types of Dried Copra

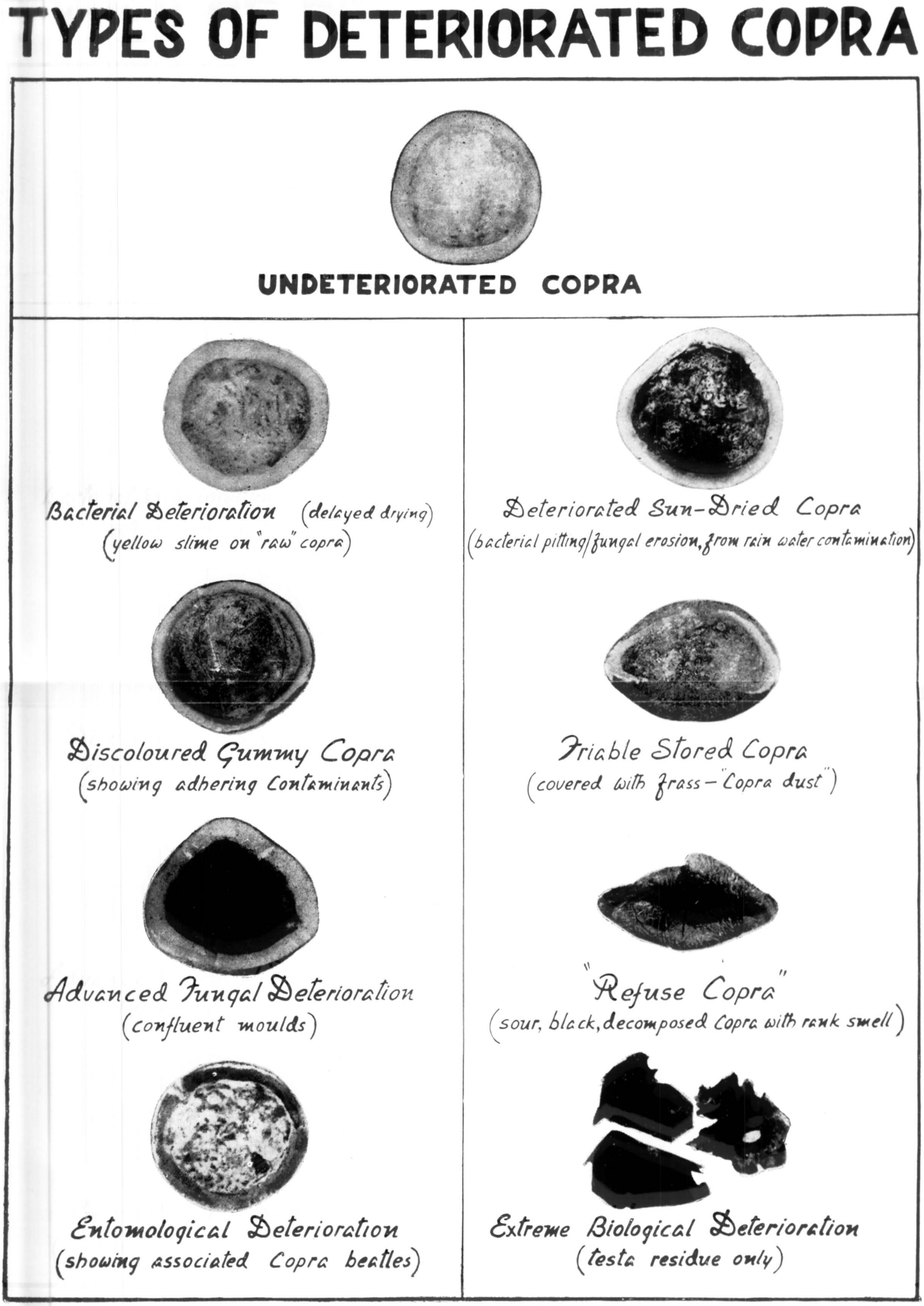


Fig. 8

Types of Deteriorated Copra

## CONCLUSION

The principal use of commercial copra is the manufacture of oil. It is a safe assumption that the greatest part of the commercial supply of coconut oil will continue to be made from copra by conventional methods for many years to come. Since consumers of coconut oil require an odourless oil of light colour and of low free fatty acid content the importance of producing quality copra should be appreciated by copra producers, marketing authorities and exporters alike.

Except in such rare instances as damage at sea, almost every case of inferior quality could be traced back to causes in the country of origin. Since proper handling, drying, storage and shipment of copra all have an important bearing on the final quality of the product, producers and consumers should appreciate each other's problems and make concerted efforts towards a general improvement of quality which should doubtless pay dividends to the industry.

## LIST OF LITERATURE REFERENCES CITED


1. C.D.V. Georgi. Malayan Agricultural Journal, 1929, **17**, p. 335.
2. F.C. Cooke "Investigations on Coconuts and Coconut Products". 1932. Bull. No. 8 of the Dept. Agric., S.S. and F.M.S., p. 67.
3. J. Fritsch. "Fabrication at Raffinage des Huiles Vegetales". 1931. p. 450.
4. F.E.H. Koch, in Schonfeld, "Chemie und Technologie der Fette and Fette produckte", 1936, 1, p. 520.
5. J.S. Patel "The Coconut", Madras, 1938, p. 211.
6. A. Aten, M. Manni and F.C. Cooke, "Copra Processing in Rural Industries" (FAO Agricultural Development Paper No. 63).
7. W.V.D· Pieris. "The Manufacture of Copra in the Pacific Islands". (SPC Technical Paper No. 82).
8. H.S. Walker. Philippine Journal of Science (1906), **1**, 117-142.
9. H.C. Brill, H.O. Parker, and Yates, Philippine Journal of Science, (1917), **12**, 95-110.
10. V.G. Lava. The Philippine Agriculturist, (1928). XVI, pp. 461-469.
11. F.R. Passmore. Bull. Imp. Inst. 1931, **29**, (2), 171-180.