CONTRIBUTIONS FROM THE COCONUT RESEARCH SCHEME (CEYLON)

STUDIES ON THE COCONUT PALM—II

ON THE RELATION BETWEEN THE WEIGHT OF HUSKED NUTS AND THE WEIGHT OF COPRA

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THE conduct of field experiments on coconuts has hitherto had to contend with the labour and the cost of curing copra from individual palms or blocks of palms in order to arrive at comparable expressions of yield.

Although there is a marked positive correlation between the number of nuts produced by palm and the weight of copra manufactured from these nuts [1], the expression of yield by the number of nuts is open to considerable error. The error introduced is due to the variability in the size of nuts from different palms and more especially from different varieties of the palm. Some varieties produce small nuts, which although present in large numbers, may produce no more copra than a moderate number of larger nuts from other varieties. As a rough estimate of yield the number of nuts is useful, but for the purpose of experimental work on individual palms or small plots of palms, the number of nuts will not be an accurate expression of yield.

As a second expression of yield, the weight of unhusked nuts may be considered. The correlation of this weight with the weight of copra is higher than that between weight of copra and the number of nuts [1]. But here too grave errors may be introduced by the progressive desiccation of the husk, which loses a considerable amount of water on storage in heaps on the field; so that it would be risky to attempt to establish a definite numerical relation between the weight of unhusked nuts and the weight of copra, since this relation would alter with varying degrees of dryness of the husk.

The third method of expressing yield is by making use of the weight of husked nut; and it is the purpose of this paper to show that this is the most satisfactory and least troublesome method of arriving at a reliable expression of yield. In this case, the variability in size of nut which introduces an error into the first method, and the error due to drying of the husk introduced into the second method are avoided.

In 1933 Belgrave and Lambourne [2] stated that there was a "remarkably close relationship between the weight of husked nut and meat content". This relation was confirmed by the present writer who found further that in a particular experiment involving two hundred and sixty-three palms the correlation coefficient between weight of husked nuts and weight of copra was as high as +0·96.

Since the correlation coefficient was very high, it was thought that, perhaps, there was a simple numerical relation between the two variables. In order to ascertain whether this was so, the nuts from two hundred and sixty palms, divided into twenty-six blocks of ten trees each, were separately husked, weighed and cured for copra. The results of this experiment are given in table I. It will be seen that the correlation coefficient between weight of husked nuts and weight of copra was +0·984 and that the regression coefficient was 0·335.

TABLE I

Data obtained from 250 palms on Bandirippuwa Estate

Tree Numbers	No. of Nuts	Weight of Husked Nuts	Weight of Copra	$\frac{\text{Wt. of Copra} \times 100}{\text{Wt. of Husked Nuts}}$
1- 10	30	18·25	6·00	32·90
11- 21	44	30·25	10·00	33·05
22- 31	33	25·00	8·25	33·00
32- 42	50	34·50	11·00	31·90
43- 55	21	14·75	4·75	32·30
56- 66	29	20·25	7·00	34·60
67- 76	32	24·00	8·00	33·33
77- 89	40	28·50	9·50	33·33
90-101	32	22·50	7·50	33·33
102-111	40	28·25	9·75	34·50
112-121	38	27·75	9·25	33·33
122-132	57	37·50	12·50	33·33
133-145	29	24·50	7·75	31·60
146-158	50	31·25	11·25	36·00
159-169	27	17·75	6·00	33·80
170-182	47	31·82	10·25	32·20
183-192	44	35·00	11·50	32·90
193-204	38	27·28	9·50	34·80
205-214	35	25·25	7·50	29·70
215-228	42	31·00	10·50	33·90
229-244	33	25·25	8·50	33·70
245-256	32	24·25	8·00	33·00
257-267	31	24·25	7·75	32·00
268-279	35	25·00	8·25	33·00
280-289	33	27·00	8·75	32·40
290-300	32	24·25	8·00	33·00

$r = +0·984$
$b = 0·335$

The last column in the table shows that the relation that was sought for, namely the percentage ratio between weight of copra and weight of husked nuts, approximated to 33⅓ per cent., which meant that in this experiment the weight of copra was approximately equal to one-third the weight of the husked nuts.

It was realised that a relation of this sort, if established, would be of great use in minimising the labour involved in field experimentation with coconuts. It has been stated already that although the best expression of yield is the weight of copra, the process of curing copra in little lots is associated with many disadvantages which may be enumerated as follows :

1. The separate lots of nuts have to be carted from various positions in the field to the kiln, which may be some distance away, and during carting and unloading at the kiln there is always the danger of mixing the nuts from different units and of the occurrence of losses difficult to trace.

2. Losses due to pieces of the kernel being chipped off during splitting of the nuts on the barbecue are unavoidable.

3. Kiln space being limited, all the separate lots of nuts from a large number of experimental units cannot be cured at the same time; and differences in sun-drying and subsequent firing procedure at the different shifts will result in the various lots not being subjected to the same treatment.

4. Drying will seldom be uniform and the rate of drying will be different in the different layers of kernels on the kiln-platform.

5. Mixing and losses during curing always occur.

6. Errors due to inaccuracies in the weighing machine are unavoidable, especially if spring balances are being used and small weights recorded.

7. To the foregoing disadvantages may be added the great labour and cost involved in curing a large number of separate parcels of nuts.

In order to find out whether the relation between husked nut and copra, as mentioned above, could be regarded as a general relation, the experiment was repeated on the nuts of a group of palms throughout eight picks from October, 1933, to

December, 1934. The results are given in table II. & table III. Table II gives the percentage ratios, $\frac{\text{Wt. of copra} \times 100}{\text{Wt. of husked nuts}}$, the correlation coefficient and regression coefficient for the eight picks. The correlation coefficients for the individual picks are very high, approximating to +0·98; but there is considerable fluctuation in the percentage ratio and the regression coefficients, and the former does not approach very closely to 33⅓ per cent. as in the original experiment. In four cases out of eight the relation fluctuates round 32 per cent., in three cases round 30 per cent., whilst in one case it falls to almost 28 per cent.

TABLE II

Percentage Ratio between weight of Husked Nuts and weight of Copra for 8 picks, with their Correlation and Regression Coefficients.

Date of Pick	Average $\frac{\text{Wt. of Copra} \times 100}{\text{Wt. of Husked Nuts}}$	Correlation Coefficient	Regression Coefficient
16-10-33	32·37	+0·979	0·343
16-12-33	29·53	+0·967	0·289
19-2-34	30·49	+0·980	0·323
16-4-34	32·00	+0·979	0·321
19-6-34	29·91	+0·975	0·300
21-8-34	31·61	+0·982	0·331
16-10-34	27·92	+0·985	0·295
21-12-34	32·36	+0·983	0·312

The analysis of variance and covariance for the eight picks on the weights of husked nuts and copra weighed for numbers of nuts in samples is given in table III. It can be seen that the "Within Picks" correlation coefficient is +0·979.

The differences in the relation at different picks may be due to (a) real discrepancies, (b) discrepancies due to lack of uniformity in experimental procedure, most probably over-drying, and (c) discrepancies due to the presence of immature nuts in the samples, the copra from which may not bear the same relation to husked nuts as with mature nuts.

In order to test whether the presence of immature nuts tended to decrease the percentage relation, the first four bunches of eighty-four palms were picked and cured separately. The results for the first three bunches are given in table IV. All the lots were somewhat over-dried, hence the percentage relation

TABLE III

Analysis of Variance & Covariance

Source of Variation	Degrees of Freedom	Sums of Squares		Sums of Products	Mean Variances		Mean Covariance	Correlation Coefficient
		Husked Nuts	Copra		Husked Nuts	Copra		
Between Picks	7	15758·9298	1524·2749	4628·3742	2251·276	217·754	661·196	+0·944
Within Picks	710	126159·3323	12986·0055	39607·6240	17·327	1·784	5·440	+0·979
Total	717	141918·2621	14510·2804	44235·9982	—	—	—	+0·975

TABLE IV

Percentage Ratio of Weight of Copra to Weight of Husked Nuts of Bunches of Different Degrees of Maturity

Number of Bunch	Number of nuts	Weight of Husked Nuts	Weight of Copra	Wt. of Copra × 100 / Wt. of Husked Nuts
1. Ripe	968	863·25	265·25	30·7
2. Ripe	1061	903·00	274·25	30·5
3. Immature	309	281·00	82·00	29·2

was less than 33⅓ per cent. But it will be seen that the nuts of the first and second bunches which were ripe gave nearly the same relation, whereas the third bunch nuts, which were immature, gave a considerably lower relation. 31 nuts of the fourth bunch which were quite immature were also cured, and for these the relation dropped to 26·6 per cent. This shows that the presence of immature nuts in a sample tends to lower the percentage relation between weight of husked nuts and weight of copra. As far as this experiment goes, keeping in mind the over-drying which was observed, the percentage relation for mature nuts is well above 30 per cent.

Unequal drying of copra on the kiln-platform is a thing that is commonly noticed. While some halves are almost completely dry, with the moisture percentage down to 8 per cent., others are still only partially dried and require further firing. These later firings must, of necessity, over-dry those halves that are already down to the optimum moisture percentage.

In order to test this experimentally, 500 nuts were taken from a heap on the field and divided up into 10 lots of 50 nuts each. They were then husked and each lot of husked nuts was weighed separately, after which they were split open and left in the sun for 5½ hours from 11 a.m. to 4·30 p.m. At 4·30 p.m. the halves of each lot were put into wire-netting bags specially made for the purpose and fired. [Note.—For curing small samples of nuts, wire-mesh bags have been found to be most useful. The bags we use are made of ½-in. mesh and are 3 ft. long by 2 ft. wide. Owing to the smallness of the mesh no pieces of copra are lost. The bags are strong, not damaged by heat, and easy to stack and handle on the kiln.]

At 9·15 on the next morning the ten lots were weighed and spread out in the sun. Sun-drying continued till 4·30 p m. when they were put back in the kiln and fired. This procedure was continued for three more days, so that the copra received three sun-dryings and five kiln-dryings.

In the afternoon of the third day of drying, that is after three sun-dryings and two kiln-dryings, it was noticed that all the copra was not drying uniformly. Some halves appeared to be quite dry, while others were still moist.

In the afternoon of the fourth day, that is after another kiln and sun-drying it was noticed that in most cases the drying was complete, but there were still some halves that did not appear to be quite dry. This necessitated a further drying.

These observations indicate that copra in kilns does not dry uniformly with the result that a great part of it becomes over-dried, leading to a decrease in weight in the final product. This lack of uniformity, in drying is mainly due, as has been mentioned already, to the presence of immature nuts.

The results of this experiment are given in table V. The stages in columns 4 and 5 are as follows:

Stage	1	After	1	sun-drying	and	1	kiln-drying
,,	2	,,	2	sun-dryings	and	2	kiln-dryings
,,	3	,,	3	,,	,,	2	,,	,,
,,	4	,,	3	,,	,,	3	,,	,,
,,	5	,,	3	,,	,,	4	,,	,,
,,	6	,,	3	,,	,,	5	,,	,,

All weights of copra are given corrected for weight of shells, which were not actually removed till after 2 sun-dryings and 2 kiln-dryings.

TABLE V

Progressive Loss of Moisture in Copra during Drying and Changes in

$$\text{Ratio} \frac{\text{Wt. of Copra} \times 100}{\text{Wt. of Husked Nuts}}$$

Lot No.	No. of Nuts	Wt. of Husked Nuts	Wt. of Copra	Wt. of Copra × 100 / Wt. of Husked Nuts
1	50	45·50	1.18.27	40·2
			2.15.75	34·6
			3.15.00	33.0
			4.14.50	31·9
			5.13.75	30·2
			6.13.50	29·7
2	50	43·75	1.17.77	40.6
			2.15.25	34·8
			3.14.50	33·1
			4.14.00	32·0
			5.13.50	30·9
			6.13.25	30·3
3	50	46·25	1.18.25	39·5
			2.16.00	34.6
			3.15.25	33·0
			4.14.75	31·9
			5.14.25	30·8
			6.13.75	29·7

TABLE V—*(Contd.)*

Lot No.	No. of Nuts	Wt. of Husked Nuts	Wt. of Copra	Wt. of Copra × 100 / Wt. of Husked Nuts
4	50	45·00	1.17.27	38·4
			2.15.50	34·4
			3.15.00	33·3
			4.14.50	32·2
			5.14.00	31·1
			6.13.50	30·1
5	50	47·50	1.17.50	36·8
			2.16.00	33·7
			3.15.00	31·6
			4.14.75	31.1
			5.14.25	30·0
			6.14.00	29·5
6	50	47·25	1.18.00	38·1
			2.16.00	33·9
			3.15.25	32.3
			4.15.00	31.8
			5.14.50	30·7
			6.14.25	30.2
7	50	48·25	1.17.75	36.8
			2.15.75	32.7
			3.15.25	31·6
			4.14.75	30.7
			5.14.25	29·5
			6.14.00	29.0
8	50	47·25	1.17.50	37·0
			2.15.50	32·8
			3.15.00	31·8
			4.14.50	30·7
			5.14.00	29·6
			6.13.75	29·2
9	50	44·75	1.16.28	36·4
			2.14.75	33.0
			3.14.25	31·8
			4.14.00	31·3
			5.13.50	30·2
			6.13.25	29·6
10	50	47·50	1.16.75	35·3
			2.15.50	32·6
			3.14.75	31·1
			4.14.50	30·5
			5.14.00	29·5
			6.13.75	29·0

Column 5 in the table shows that the relation $\frac{\text{Wt. of copra} \times 100}{\text{Wt. of husked nuts}}$ dropped gradually during the six stages to 29—30 per cent., at which stage the large majority of the kernels were over-dry.

The observation regarding unequal drying was made at stage 3, when the optimum state of dryness had been reached by all the kernels except a few halves which were still too moist and leathery. At this stage the mean percentage relation for the ten lots was 32·3 per cent. At most, only one more firing was necessary which would have brought down the relation to 31·4 per cent. The 5th and 6th firings which were given for the benefit of the few leathery half-kernels resulted in the over-drying of the samples as a whole.

A further experiment was carried out on the progressive loss of moisture during copra drying. Two lots of 100 ripe nuts each were taken and processed in the usual manner. They were subjected to four sun-dryings and four kiln-dryings. After each kiln-drying and sun-drying, a small sample of the kernels of each lot was taken and analysed for moisture content.

The results obtained are given in table VI.

It will be noticed that when the copra was quite dry the percentage of moisture had dropped to 7 to 8 per cent., and the percentage ratio between copra and husked nuts was in the first case 32·37 per cent. and in the second case 33·02 per cent., these figures not being greatly discrepant from the ideal ratio of 33·33 per cent.

The foregoing experiments were carried out on parcels of nuts. It was now considered desirable to carry out a similar investigation on single nuts. Consequently, 50 ripe nuts were taken from a heap and treated individually in the customary manner. Drying, however, was carried out entirely in the sun in order to ensure that the temperature and humidity conditions were exactly the same for all nuts during the drying period.

All the fifty nuts were given, on the average, seven sun-days of six hours each, equal to forty-two hours in the sun. As a rule, six sun-days or thirty-six sun-hours are sufficient, if during that time there is maximum sunshine with low humidity. But the period during which this experiment was carried out was not uniformly bright, the sun being completely overcast on three and a half days out of the seven. This necessitated an extra six hours of drying.

The chief observation that was made was that some of the kernels dried out quicker than others and when the whole sample was ready for weighing these kernels were over-dried, though not very much so.

TABLE VI

Progressive Loss of Moisture on drying Copra

Lot 1 : Number of Nuts—100 Weight of Husked Nuts : 87·25 Kg.

Lot 2 : ,, ,, —100 ,, ,, ,, : 86·50 Kg.

Stage	Intervals of Drying	Lot 1			Lot 2		
		Weight of Copra	Wt. of Copra × 100 / Wt. of Husked Nuts	% Moisture	Weight of Copra	Wt. of Copra × 100 / Wt. of Husked Nuts	% Moisture
1	After 1st Sun-Drying	—	—	23·9	—	—	24·3
2	,, 1st Kiln ,,	—	—	23·8(?)	—	—	24·2(?)
3	,, 2nd Sun ,,	—	—	19·9	—	—	22·1
4	,, 2nd Kiln ,,	31·30	35·87	16·0	31·22	36·09	13·5
5	,, 3rd Sun ,,	29·66	33·99	13·9	29·92	34·59	12·1
6	,, 3rd Kiln ,,	29·04	33·28	11·6	29·07	33·61	9·7
7	,, 4th Sun ,,	28·60	32·78	8·6	28·67	33·14	9·1
8	,, 4th Kiln ,,	28·24	32·37	7·2	28·56	33·02	7·8

TABLE VII

Summary of Experiments

Experiment Number	Number of Samples	Average No. of Nuts per sample	% Ratio between wt. of Husked Nuts and wt. of Copra	Number of Table in Text	Remarks
1	26	37	33·10	Table I	
2	718	10	30·77	Table II	A fair amount of over-drying noted owing to the difficulty of controlling the uniform drying of a large number of small samples.
3	(a) 1 (b) 1 (c) 1 (d) 1	968 1061 309 31	30·7 30·5 29·2 26·6	Table IV	(a) and (b) represent 1st and 2nd bunch nuts; (c) and (d) represent 3rd and 4th bunch nuts; the large majority of which were unripe and gave leathery No. 2 copra.
4	10	50	Stage 3—32·26 Stage 6—29·62	Table V	Stage (3).—Majority of kernels were dry and needed no further firing. Stage (6).—The dried kernels of stage 3 were now definitely over-dried.
5	2	100	Sample (1). 32·37 Sample (2). 33·02	Table VI	% moisture of sample (1) was 7·2 and of sample (2) 7.8.
6	50	1	32·20	—	Average % moisture was 7·8 %

The pairs of half-kernels of individual nuts were weighed and a sample of copra from each nut was analysed for moisture content.

The results of this experiment could be summarised as follows :—

1. The correlation coefficient between weight of husked nut and weight of copra was found to be +0·971.
2. The average percentage ratio between copra and husked nut was 32·2 per cent. with a standard deviation of 2·214 per cent.
3. The average percentage of moisture in the copra was 7·82 per cent. with a standard deviation of 0·59 per cent.

SUMMARY

The results of the foregoing experiments are summarised in table VII.

(a) It may be stated that with dead ripe nuts and optimum drying the percentage ratio between weight of copra and weight of husked nuts approximates to 33 1/3 per cent.

(b) Over-drying, which normally takes place when immature nuts are present which require a larger number of firings or sun-dryings than ripe nuts; tends to lower this ratio to about 30 per cent.

(c) With uniformly ripe nuts, and average drying conditions the ratio is between 32 and 33 per cent.

(d) For purposes of field experimentation it is recommended that 32 per cent. be adopted as the percentage ratio between weight of copra and weight of husked nuts.

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HISTORICAL NOTE

There is nothing new under the sun. The author has been told that the percentage relation between weight of husked nuts

and weight of copra, which has now been established experimentally, was known many years ago to a representative of a large commercial firm in Ceylon buying coconuts for the manufacture of oil and desiccated coconuts. As a buyer, he estimated the weight of copra as being equal to 30 per cent. of the weight of husked nuts, which is 2 per cent. less than the figure arrived at in the present investigations.

It might also be of interest to add that he considered the weight of desiccated coconut as being approximately equal to 25 per cent. of the weight of husked nuts.

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