SULPHUR DEFICIENCY IN COCONUTS, A WIDESPREAD FIELD CONDITION IN PAPUA AND NEW GUINEA.

PART II : THE EFFECT OF SULPHUR DEFICIENCY ON COPRA QUALITY.

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ABSTRACT.

Sulphur deficiency causes coconut palms to produce defective 'rubbery' copra which has poor physical and chemical qualities. The copra has a low oil content, high moisture absorbing properties, high sugar, ash and nitrogen contents. The oil extracted contains high amounts of unsaturated fatty acids causing high iodine values and low saponification values. It is shown that this is probably due to the high proportion of testa to kernel.

Rubbery copra contains lower amounts of sulphate than normal copra and can be improved in quality by ameliorating the sulphur deficiency. At present it forms a significant proportion of the copra production of Papua and New Guinea.

References have been made in the preceding paper (Southern 1967) to the occurrence in Papua and New Guinea of abnormal copra, locally termed 'rubbery copra'. There are few reports of such material being found in manufactured copra in other coconut growing countries.

Cooke (1937) described the properties of rubbery copra as found in Malaya, as follows :—

" Defective nuts produce rubbery copra, the copra obtained from such nuts, even if ripe, being heavily wrinkled, yellow, distorted and plastic after drying under the best conditions possible, and such copra is particularly liable to deteriorate. Copra from defective nuts can be distinguished from copra of similar texture which is obtained from unripe nuts because the testa or brown skin of such copra is thick, dark brown and adhering. Copra from unripe nuts presents a bald appearance as much of the skin is retained by the shell.

" In certain districts of Malaya, there is a pronounced tendency for nuts to be defective which, coupled with unfavourable climatic conditions, seems to explain the particular difficulty of producing good copra in Malaya. The physiological aspect of the problem, which is very complex, is under investigation by the Soils Chemist."

Cooke also describes the chemical and physical properties of rubbery copra :—

" While the moisture content of the wet, raw meat from defective nuts is exceptionally high, the oil content (wet basis) is exceptionally low. Nevertheless, when the large amount of contained moisture is evaporated, the average oil content (dry basis) of the resulting rubbery copra is normal, i.e., the average oil —tissue ratio is not abnormal.

" Individual pieces of rubbery copra, however show wide variations as regards oil content and the following may be quoted as typical :—

58.0, 62.1, 63.8, 66.2, 67.4, 69.4, 69.6 per cent.

Average oil content (dry basis) ;—65.46 per cent.

" Since the average oil content is normal, it might appear surprising that the oil millers should regard rubberiness as one of the worst defects of copra on the grounds that rubbery copra gives a poorer yield of oil. The reason is that such copra does not break up easily, but gives a coarse meal which is elastic, which does not part with its oil readily and which, moreover, being spongy, can reabsorb oil when the pressure is removed. A further serious objection to such copra is that it will jam the conveying machinery and clog the silos and hoppers."

Dwyer (1937) reported the presence in the Bismarck Archipelago of defective coconuts showing a thin, leathery, soft kernel, which did not dry out properly when dried in the normal manner. The resultant copra was described as soft, flexible and leathery, often becoming brown

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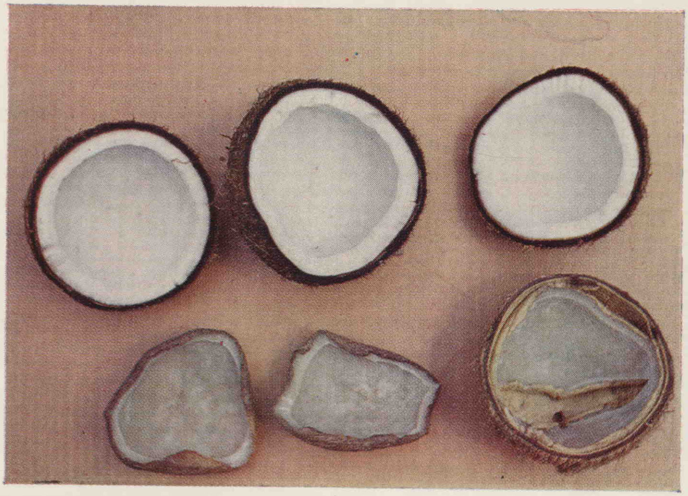

Plate I.—Rubbery copra produced from appərently normal nuts from sulphur deficient palms.

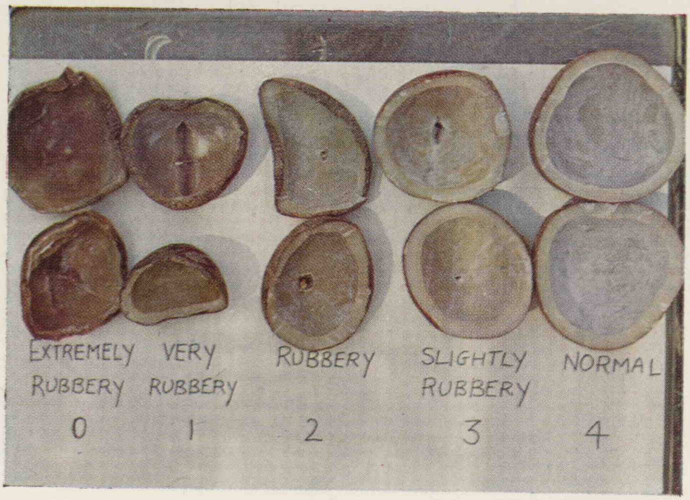

Plate II.—Pieces of copra showing varying degrees of rubberiness and being typical of the categories selected.

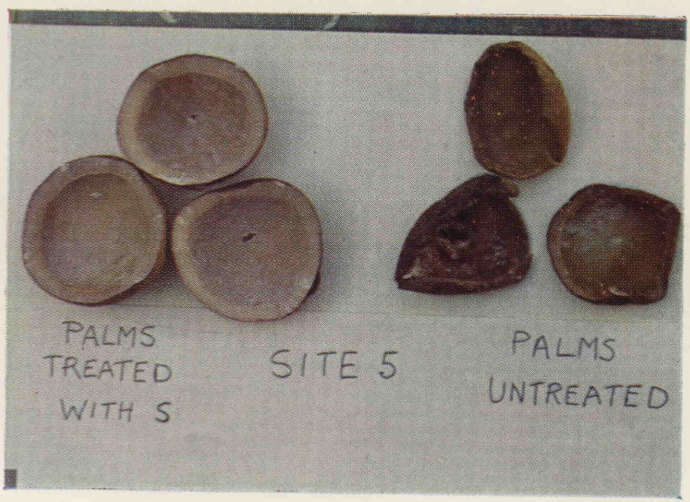

Plate III.—The improvement in copra quality following treatment of palms with sulphur.

in colour, and being of poor appearance and quality. Dwyer also considered the occurrence as having a nutritional or physiological cause.

There is no doubt that in this Territory, copra of rubbery quality, similar to that described by Cooke and Dwyer, is found throughout all major copra producing areas. Unpublished data by Murty (1958) showed that an estimated 2,000 tons of copra containing an admixture of rubbery material passed through inspection centres from July, 1957, to June, 1958. This was over two per cent. of the total production. Over 100 plantations had reports of rubbery copra occurring in their shipments. When it is considered that much of the rubbery copra produced is hand sorted on plantations and is not included in copra prepared for export, it is likely that this defective copra represents a significant proportion of the total production.

It has now been shown that rubbery copra is produced by coconut palms affected by sulphur deficiency and that copra quality can be improved by treating affected palms with sulphur (Southern 1967). Some of the effects of sulphur deficiency on the physical and chemical characteristics of copra are outlined in this paper.

THE PHYSICAL NATURE OF RUBBERY COPRA.

Fresh coconut meat from sulphur deficient palms cannot be distinguished from that obtained from healthy palms. The meat often has a rather wrinkled inside surface but this abnormality is also found in nuts from potassium deficient palms and even in some nuts from apparently healthy and productive palms. The nuts themselves are generally small in size while they may be any shape.

All the nuts examined in these investigations had the appearance of fully mature nuts ; in fact the embryo had commenced to develop in many cases. They were all collected on the ground and husks were well dried out. There was therefore no possibility that the rubbery copra obtained was due to nut immaturity, which can produce a thin type of leathery copra. *Plate* I shows that the affected nuts have normal meat thickness. However, when they are dried the meat collapses into thin, rubbery or leathery copra, often darker in colour than usual. The copra frequently splits and becomes distorted in shape. In severe cases the testa becomes very wrinkled. The coloured photograph clearly shows the type of copra produced from apparently normal nuts.

The loss in weight on drying is much more than in normal manufacture, a property also observed by Cooke. From tests carried out on copra from an experimental site it was found that 100 lb. of coconut meat from sulphur deficient palms would produce only about 38 lb. of rubbery copra, compared to the production of about 58 lb. of normal copra from non-deficient palms.

Tests have also shown that different drying techniques have little or no influence on the nature and quality of the final product. Thus halves of the same nut dried in the oven or the refrigerator produced copra of similar characteristics.

In the usual hot humid atmosphere of the tropics, this defective copra will absorb moisture rapidly and its physical characteristics become more obvious. It becomes flexible and almost elastic, giving rise to the term 'rubbery copra'. It is these adverse physical properties which cause milling and extraction problems. The texture of this copra, its distorted and cracked shape and its generally thinner nature enable it to be readily differentiated from normal copra.

THE CHEMICAL CHARACTERISTICS OF RUBBERY COPRA.

To examine the chemical properties of various degrees of rubbery copra, representative samples of rubbery and normal copra were selected from a large amount of copra collected from the Experimental Site 1 described in the previous paper. These were placed in five categories as follows :—

Category 0 .... Extremely Rubbery.
Category 1 .... Very Rubbery.
Category 2 .... Rubbery.
Category 3 .... Slightly Rubbery.
Category 4 .... Normal.

Typical pieces of copra in each of these categories are shown in *Plate* 2. The grades are mainly distinguished by thickness and texture and differences are not clearly brought out by the illustration.

All copra was dried at 50° to 60°C in a forced draft hot air oven. Prior to this samples were washed thoroughly to remove traces of coconut water from the surface of the meat.

Following rapid comminution in a blendor, determinations were made of moisture, oil content, total sugars, nitrogen, sulphur and ash. The results of these analyses are shown in *Table* 1.

Some more detailed comments on the determination and results are as follows :—

(*a*) *Moisture Content.*

The dried ground samples were left for a short time exposed to a humid atmosphere before any determinations were carried out. Moisture determinations showed that rubbery copra had a greater tendency to absorb moisture than normal copra. This is a well known property of rubbery copra and has been remarked upon by Cooke. It has been generally observed in these investigations that fungus and bacterial growth would form on the surface of pieces of rubbery copra long before normal pieces of copra were affected. This is a serious disadvantage in that shipments of copra containing rubbery material would deteriorate much faster than those of normal copra.

The affinity for moisture of rubbery copra may be due to the higher content of nonfatty material, in particular the higher content of minerals.

(*b*) *Oil Content.*

The oil was determined by extracting five grams of ground material with petroleum ether in a soxhlet extraction unit. The material was reground three times in a stainless steel mill until the total oil content was almost constant. Less than 0.3 per cent. oil was recovered in the final grinding and extraction.

The oil content of pieces of rubbery copra is very much less than that of normal copra and *Table* 1 shows that the oil content is well correlated with the degree of rubberiness. Other samples of rubbery copra have invariably given low oil contents, as *Table* 2 shows. These results were the analyses of a number of nuts rather than single nuts.

Table 2.—**Oil Contents of Copra, Rubbery and Non-Rubbery.**

Location.	Category.	Description.	Oil Content (Per Cent. Dry Basis).
Site 4	2	Rubbery	53.6
Site 5 (*a*)	0	Extremely Rubbery	39.1
Site 5 (*b*)	0	Extremely Rubbery	41.6
Site 6 (*a*)	1	Very Rubbery	47.8
Site 6 (*b*)	1	Very Rubbery	46.6
Site 6 (*c*)	1	Very Rubbery	51.7
Site 6 (*d*)	1	Very Rubbery	42.8
Site 7	1	Very Rubbery	47.7
Site 7	2	Rubbery	56.5
Site 7	3	Slightly Rubbery	61.8
Kokopo	1	Very Rubbery	47.5

Figure 1 shows that the oil contents obtained correlate well with the categories of quality determined by visual and physical examination. The diagram is a summary of results presented in *Tables* 1 and 2.

While Cooke (1937) considered that Malayan 'rubbery copra' had a fairly normal oil content (expressed on a dry basis), it is evident that the Papua and New Guinea material has a very low oil content. Shipments which contain significant proportions of rubbery copra are therefore likely to have a lower oil content than usual. Moreover, the difficulty in extracting oil from rubbery pieces because of their adverse physical nature would make rubbery copra, with its lower oil content, even more unattractive to coconut oil manufacturers.

Table 1.—**Analysis of Various Grades of Rubbery Copra.**

Category.	Description.	Moisture Per Cent.	Oil Per Cent Dry Basis	Total Sugars Per Cent Dry Basis	Ash Per Cent. Dry Basis.	Nitrogen Per Cent. Dry Basis.	Sulphate p.p.m.S Dry Basis.
0	Extremely Rubbery	4.8	38.4	29.5	4.0	2.52	31
1	Very Rubbery	4.8	47.0	32.4	3.2	1.95	37
2	Rubbery	4.3	51.6	32.9	2.8	1.65	22
3	Slightly Rubbery	2.5	64.4	20.0	2.5	1.32	107
4	Normal	2.4	64.9	21.5	2.3	1.19	141

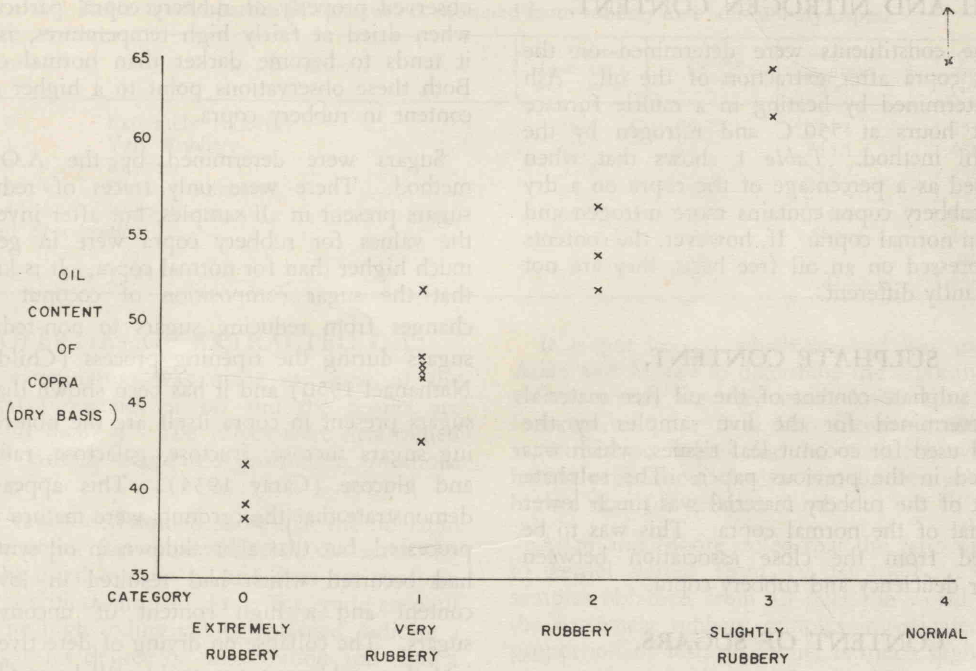

FIG I. OIL CONTENT OF COPRA, VARIOUS CATEGORIES.

It has been shown in the previous paper how copra quality can be improved by the use of sulphur or sulphate fertilizers. An outstanding example of the improvement gained is shown in *Plate* III. Two years after application of 2 lb. sulphur the quality improved from Category 0 (extremely rubbery) to Category 4 (Normal). This example occurred at Kokopo on Experimental Site 5. The oil content of samples increased from 40 per cent. to 65 per cent. on a dry basis.

In Experimental Site 1, oil contents of copra samples were determined at frequent intervals during the course of the fertilizer trial. With the improvement in copra quality it would be expected that the oil content of the copra would increase for the sulphur treated palms and this is strikingly shown in *Table* 3 and *Figure* 2.

It is surprising to note that significant increases in oil content were obtained six months following treatment with sulphate fertilizers. The action of elemental sulphur was slower than that of the soluble sulphate fertilizers although the end result was the same. The increase in oil content is thus associated with quality improvement, foliage colour improvement, frond increases and sulphate content as shown in the previous paper.

Table 3.—Effect of treatment on oil content of Copra, Site 1. (Per cent. oil on dry basis.)

Sampling.	Date.	Nil Treatment.	Sulphur.	Sulphate of Ammonia.	Sulphate of Potash.
1	19.7.1965	43.7	46.8	45.4	48.7
2	11.10.1965	41.4	46.8	51.1	49.9
3	10.1.1966	46.6	54.4	59.4	57.2
4	16.2.1966	48.9	53.7	64.0	64.8
5	28.2.1966	51.0	59.9	62.6	63.0
6	14.3.1966	54.3	61.0	64.3	62.7
7	28.3.1966	53.3	64.4	65.2	65.2
8	18.4.1966	48.8	62.1	63.8	64.5
9	2.5.1966	49.5	62.9	65.3	66.7
10	3.6.1966	53.0	63.3	64.7	63.8
11	24.6.1966	47.4	62.8	64.3	63.6
12	5.7.1966	46.7	60.4	61.5	60.6

ASH AND NITROGEN CONTENT.

These constituents were determined on the ground copra after extraction of the oil. Ash was determined by heating in a muffle furnace for six hours at 550°C and nitrogen by the Kjeldahl method. *Table* 1 shows that when expressed as a percentage of the copra on a dry basis, rubbery copra contains more nitrogen and ash than normal copra. If, however, the contents are expressed on an oil free basis, they are not significantly different.

SULPHATE CONTENT.

The sulphate content of the oil free material was determined for the five samples by the method used for coconut leaf tissues, which was indicated in the previous paper. The sulphate content of the rubbery material was much lower than that of the normal copra. This was to be expected from the close association between sulphur deficiency and rubbery copra.

CONTENT OF SUGARS.

It has been observed that defective nuts, either as green meat or as the dried rubbery copra, are noticeably sweeter to the taste. Another observed property of rubbery copra, particularly when dried at fairly high temperatures, is that it tends to become darker than normal copra. Both these observations point to a higher sugar content in rubbery copra.

Sugars were determined by the A.O.A.C. method. There were only traces of reducing sugars present in all samples, but after inversion the values for rubbery copra were in general much higher than for normal copra. It is known that the sugar composition of coconut water changes from reducing sugars to non-reducing sugars during the ripening process (Child and Nathanael 1950) and it has been shown that the sugars present in copra itself are the non-reducing sugars sucrose, fructose, galactose, raffinose and glucose (Caray 1934). This appears to demonstrate that the coconuts were mature when processed, but that a breakdown in oil synthesis had occurred which had resulted in low oil content and a high content of unconverted sugars. The collapse on drying of defective nuts into thin, rubbery copra could well be attributed to the fact that the cells did not contain their normal quota of oil.

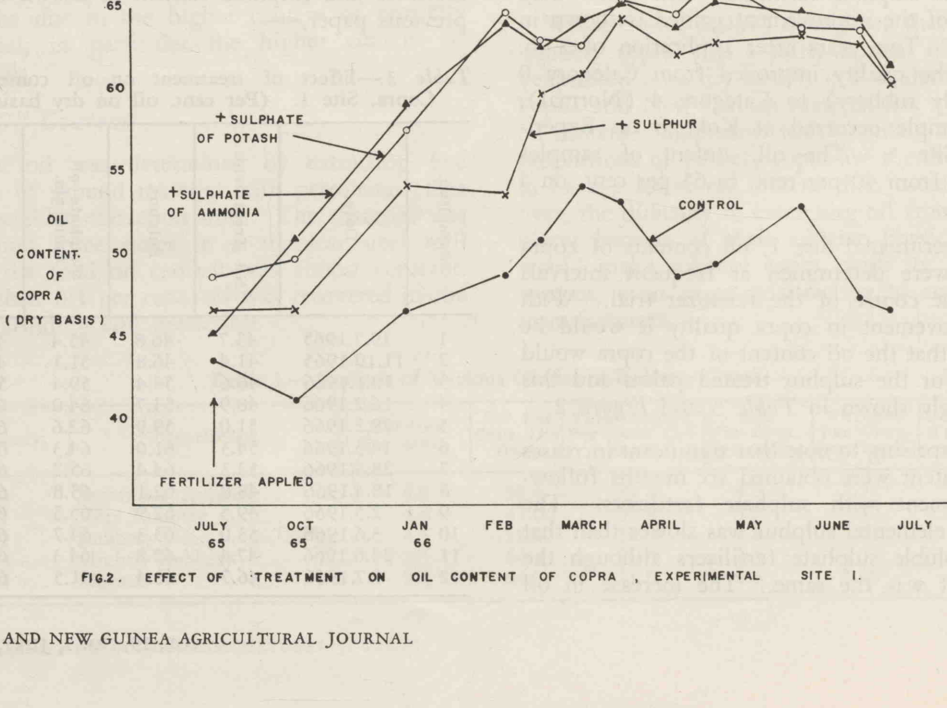

FIG.2. EFFECT OF TREATMENT ON OIL CONTENT OF COPRA, EXPERIMENTAL SITE I.

Table 4.—**Properties of coconut oil extracted from rubbery and non-rubbery copra.**

Category.	Description.	Oil Content (per cent. dry basis).	Iodine Value.	Saponification Value.	Refractive Index (40°C).
0	Extremely rubbery	38.4	20.25	234.1	1.4519
1	Very Rubbery	47.0	14.77	243.1	1.4508
2	Rubbery	51.6	12.63	245.7	1.4504
3	Slightly Rubbery	64.4	9.03	258.4	1.4490
4	Normal	64.9	7.40	264.6	1.4489
Required Specification			7.0 to	Above	1.4485 to
Range, B.S. 628 (1950)			9.5	255	1.4492

PROPERTIES OF EXTRACTED OIL.

An examination was made of some of the chemical properties of oil and the results are shown in *Table* 4. The values were determined by the British Standards Institution Methods (1950).

The values determined show that the oil from rubbery copra has quite different characteristics from the usual coconut oil and does not conform to the specifications laid down for crude coconut oil. The high iodine values obtained indicate a much greater degree of unsaturation and thus a different composition of fatty acids.

It is considered that the abnormal values obtained for these oil characteristics are likely to be due to the much greater proportion by weight which the brown testa (seed coat) represents in rubbery copra. Early work by Allan and Moore (1925) showed that testa oil had quite different characteristics and fatty acid composition from kernel oil. The resultant mixed whole oil therefore had intermediate values and composition. Thus the following results were obtained for saponification values and iodine values (*Table* 5).

Further work by Armstrong, Allan and Moore (1925) showed that the testa (or parings) oil contained 23.0 per cent. and 10.0 per cent. respectively of the unsaturated oleic and linoleic acids, compared to only 5 per cent. and 1 per cent. for the kernel oil. This would account for the higher iodine values obtained for the former oil.

It is not known which method was used by Allan and Moore to determine the saponification values, which are very much lower than usual for coconut oil. It is also surprising that the saponification values for the testa oil, with its higher proportion of oleic and linoleic acids are higher than for the kernel oil.

Allan and Moore noted that the ratio of testa to kernel varied from 1 : 10 to 1 : 25, for samples obtained from all over the world. For the extremely rubbery samples investigated, the proportion of testa to kernel is much higher, in some cases probably as high as 1 : 2 or even 1 : 1. The testa oil with its much higher proportion of unsaturated fatty acids would therefore have a great influence on the characteristics of the mixed oil and could well be responsible for the abnormal values obtained from oil from rubbery copra.

Further investigations confirmed this hypothesis. Testa free pieces of rubbery copra were analysed and these were found to have more normal oil characteristics, although their oil content was still low. Results on three samples were as shown in *Table* 6.

GENERAL DISCUSSION.

The presence of rubbery copra in shipments has been shown to have a number of deleterious effects on the physical qualities of the copra and would tend to lower the oil content, reduce its saponification value and raise the iodine value

Table 5.

—	Kernel Oil.	Testa Oil.	Whole Oil.
Saponification Value	213.4-219.3	232.5-253.5	214.2-221.0
Iodine Value	5.7- 9.3	21.5- 59.7	7.1- 10.5

Table 6.—**Characteristics of oil obtained from testa free pieces of rubbery copra.**

Category.	Description.	Oil Content (Dry Basis).	Saponification Value.	Iodine. Value.	Refractive Index.
1	Very Rubbery	43.4	248.4	7.99	1.4489
1	Very Rubbery	43.7	250.1	7.74	1.4489
3	Slightly rubbery	59.7	262.2	5.66	1.4480

and refractive index. If rubbery copra is present in significant quantities, the quality of the oil may be changed so that it does not meet the required specifications.

The occurrence of sulphur deficiency and rubbery copra is so widespread in Papua and New Guinea that the general use of sulphur containing fertilizers could increase total copra production substantially and improve the quality of the final product.

The present investigation did not proceed further in examining the biochemical processes which obviously are affected by a deficiency of sulphur and do not pursue their normal course. The literature does not appear to contain references to the role of sulphur in the formation of fats and oils in plants and this may be the first account of the effect of sulphur deficiency on oil synthesis. There is clearly an interesting and fruitful avenue of research open to bio-chemists and plant physiologists working in the tropics.

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