ECONOMIC LOSSES TO THE COCONUT INDUSTRY CONSEQUENT ON DETERIORATION OF UNDER-DRIED COPRA

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Introduction

Copra is doubtless a perishable food commodity and the amount of deterioration and depreciation that can occur in the manufactured product is indeed very great. It is considered that a proper understanding of this aspect of the subject would be of much value and importance to both producer and consumer alike.

It is known that the general standard of quality and the keeping properties of the world's copra is appallingly low in comparison with the standards of every other primary agricultural produce that enters into world trade. A variety of factors may contribute to this, and the fact remains that under typical conditions even superfine copra will not keep indefinitely but will eventually deteriorate with the passage of time. The actual period taken, and the degree of such deterioration would however be contingent on the exact circumstances of processing, handling and storage.

Owing to the lack of fixed general standards of quality in most coconut producing countries, it is in a way unfortunate that almost any kind of copra can obtain a market. The inevitable result is of course that there is no emphasis on careful processing or adequate dryage, thereby creating a continued tendency towards the production of the lowest acceptable quality for commercial purposes. This merely implies that the situation is not satisfactory and that optimum economic returns are not secured for the coconut industry, because inadequate dryage of copra always results in subsequent degenerative losses through deterioration.

In order to facilitate a good understanding of the different factors and problems involved, it is essential to consider firstly certain important theoretical and practical aspects of copra deterioration. It is then proposed to consolidate and interpret briefly in this paper the results of some preliminary laboratory studies that have been carried out by the author with the object of obtaining some sort of quantitative assessment of the extent of economic losses to the coconut producer resulting from general deterioration of under-dried copra. Besides surveying relevant information in the literature and the more important observations bearing on this subject made by previous workers, it is also proposed to discuss possible practicable methods whereby 'strictly wasteful' losses to the coconut industry could be prevented or at least kept down to a minimum.

Composition of Copra in Relation to Deterioration

The coconut kernel (or endosperm) contains reserves of stored food material for utilisation by the embryo during its germination and early phases of growth. These food constituents include the major and essential factors: fat, protein, carbohydrate, mineral salts and certain vitamins. In its fresh state the kernel also contains a good deal of moisture, which generally ranges between 42.0 and 46.0 per cent. For practical purposes therefore 44.0 per cent may be regarded as a reasonable average value for the moisture content of the fresh kernel.

It is only too well known that the freshly grated coconut meat as used for culinary purposes in some coconut growing countries has extremely poor keeping qualities and is indeed very difficult to preserve. Since the wet meat goes bad so easily, for commercial purposes the fresh kernel is generally dried down to about 6 per cent moisture content in which form its keeping qualities are decidedly improved. The product so obtained is of course the familiar copra. By far, the largest proportion of commercial copra is used for the production of coconut oil and in the milling process the residue left behind is coconut press cake or 'poonac' which is a valuable protein concentrate for dairy cattle and farm stock. Figures showing the chemical composition of a typical sample of fresh coconut kernel as compared with copra and poonac are charted in Table I below:—

TABLE I

1	2	3	4
CONSTITUENT	*Fresh Coconut Kernel* (*Typical Sample*) %	*Number One Copra* (*Average Sample*) %	*Poonac* (*Average Sample*) %
Moisture ..	44.0	6.8	9.8
Oil ..	38.2	63.7	8.1
Protein ..	4.6	7.6	21.0
Carbohydrates ..	9.7	16.1	45.1
Mineral Constituents (ASH) ..	1.2	2.0	5.5
Crude Fibre ..	2.3	3.8	10.5
Total ..	100.0	100.0	100.0

The above figures serve to demonstrate and confirm the aforementioned fact that the kernel of the coconut contains besides the mineral constituents, all three of the major food factors: protein, fat and carbohydrate. It will of course be further evident that the principal constituent is oil or fat.

With a knowledge of the nature and composition of the coconut kernel it should now be apposite to consider how and why spoilage occurs so readily with the fresh meat and the products derived from it.

Provided there is no infection of or damage to the 'soft eye' the wet white inner surface of the endosperm remains sterile until the nut is split open, when it at once provides a perfect nidus or medium for the growth and multiplication of moulds, yeasts, bacteria and associated insects. Micro-organisms in general, require for their metabolism, besides a source of carbon, also moisture, nitrogenous substances and mineral salts. Whilst a pure dry fat by itself, cannot support the growth and reproduction of such organisms, spoilage due to their activity occurs most readily in fats held in moist tissues containing the other requisite microbial nutrients which have been enumerated above. Besides containing these nutrients, it should indeed be obvious that the coconut kernel and its products constitute ideal media providing all the conditions which would favour biological deterioration.

Concomitant Changes and Characteristics of Copra Deterioration

From what has been adumbrated above it should be abundantly clear that a commodity like copra which has to withstand the vicissitudes of storage and transport for protracted periods of time is very prone indeed to deterioration and loss. On the other hand there is every possibility that these degenerative changes could be minimised by careful processing followed by judicious handling and proper storage or warehousing of the finished product.

When a coconut is split open, the freshly cut surface of the kernel comes into contact with the atmosphere which invariably carries teeming millions of putrefactive organisms and their dormant spores. Once the wet meat gets casually inoculated with these, the process of deterioration may be said to commence almost spontaneously.

The fat of the coconut is held in the endosperm in the form of tiny droplets of oil in cells possessing thin membranous cell walls. If this membrane gets damaged the contained oil oozes out rendering the surface of the copra greasy and unsightly. Whenever this happens the product becomes very vulnerable to micro-organic action, the ruptured walls of the oil cells providing supplementary protein for the activity of different organisms.

Though, in a great majority of cases the organisms which attack fatty foods (like the coconut) are of the non-pathological type, yet they can cause much damage by the production of unpleasant flavours and odours and also by the formation of unsightly fungoid growths and discolourations. It should also be mentioned that an actual loss of anhydrous copra is invariably a concomitant of this type of deterioration, the degree and quantitative loss of course varying according to the precise circumstances.

It is an undisputed biochemical fact that before the reserves of oil in the kernel can be utilised by the growing embryo they have to be broken down into simpler and more easily assimilable fractions. It is known that this is accomplished by certain fat splitting (i.e. lipolytic) organic catalysts called enzymes which are present in the tissues of the coconut kernel *outside* the oil cells. Whenever there is rupture of the oil cells the enzymes come into contact with and attack the fat globules with the production of free fatty acids and glycerine. The acids may then break down further into aldehydes and ketones which are principally responsible for the strong odours, rancid flavours and the darkening in colour which may generally be recognised as distinctive features of copra deterioration.

Nature of Chemical Changes. It should be pointed out that the actual process of decomposition in raw copra is exceedingly complicated and the mechanism of the chemical reactions involved are as yet but little understood. Coconut oil itself consists of mono, di, and triglycerides of caproic, caprylic, capric, lauric, myristic, palmitic and oleic acids together with small amounts of certain of the esters of phytosterol. It should therefore be readily appreciated that the problem itself is a highly involved one owing to the fact that the reactions are taking place in a very complex substrate consisting chiefly of complex glycerides but containing in addition, protein bodies, various types of nucleotides simple and complex carbohydrates (including cellulose) and other products in minute amounts. It is claimed that at least twenty distinct enzymes have been isolated from moulds and almost as many from bacteria. It is further known that the activity of these various enzymes and the velocity of their action is in a large measure dependent on the pH of the medium. This would imply that interactions and the end-products of any chemical reactions involved would be highly variable and complex, depending on the actual hydrogen — ion concentration of the medium (copra) in which the chemical changes are taking place.

(*NOTE* — The pH value of the fresh meat usually ranges between 6.0 and 6.8).

In broad outline the sequence of degenerative changes taking place in the heterogeneous system provided by deteriorating under-dried copra could be summarised as follows:—

Firstly, owing to a breakdown of the soft cellular surface tissue of the white meat, the non fatty solid matter of the tissue along with the sugars and proteins contained in any adhering coconut water become affected by fermentative changes. A perceptible yeasty odour usually characterises this initia stage of deterioration.

Secondly, the various glycerides of the oil that are released by the tissue breakdown are acted upon and split by lipolytic enzymes (lipase enzymes) into their component fatty acids (principally lauric acid) and glycerine. The copra itself turns decidedly sour at this stage.

Thirdly, it has been observed that the glycerine produced is fairly rapidly decomposed into various degradation products which under the oxidative influence of air, heat and light produce the condition termed *rancidity*.

Fourthly, the property of rancidity is accentuated by the decomposition of the mixed fatty acids liberated by lipase with the production of aldehydes and ketones. It is now the accepted belief that the primary cause of rancidity is not the development of acidity but auto-oxidation in the presence of moisture.

Finally, under conditions of extreme deterioration where inadequately dried copra is stored under continuously bad conditions. the ultimate products of decomposition would be gas (principally carbon monoxide) and water vapour. These end products are reckoned to be produced by the action of the enzyme carboxylase on the free fatty acids.

In general, it may be stated that the sum total of the different processes of decomposition is to produce a coloured oil containing not only the free fatty acids liberated by the action of the lipase group of enzymes but also many other products (some in minute amounts) resulting from the decomposition of protein, carbohydrates and the other organic constituents of copra. Moreover, the residual oil cake (poonac produced from deteriorated copra depreciates in nutritional value owing to loss of both proteins and carbohydrates. The oil too develops the property of rancidity owing to the further decomposition of the free fatty acids split off from the glycerides and also the presence in it of proteins and other decomposition products.

Having considered the *modus operandi* of copra deterioration it is worthy of repetition that an underlying feature of the stepwise degenerative changes is that there is always an actual quantitative loss of anhydrous copra associated with biological deterioration. It has also been shown that the ultimate products of decomposition would be gas and water vapour. Convincing factual evidence demonstrating the generation of 'moisture of decomposition' is provided in the experimental data[1] given in Table II.

TABLE II

Changes in Copra During Storage

1		2	3	4
SAMPLE		*% Moisture*	*% Oil (dry basis)*	*CONDITION OF COPRA*
GOOD DRY COPRA I	At Start ..	4.5	67.4	Clean white copra.
	After 2 months ..	5.4	68.4	Superficial mould only. Colour good.
UNDER-DRIED COPRA II	At Start ..	12.1	64.4	Clean white copra.
	After 2 months ..	64.7	23.5	Slimy, black, mite ridden, wet and rank.

For the experiment two samples of sliced copra both good in appearance, but one dried to an optimum moisture content (4.5 per cent), and the other under-dried (12.1 per cent), were stored in sealed tins. The tins were opened after two months and the samples were visually inspected and then analysed for moisture and oil contents. The results show that it is possible even for *dry copra* to produce 'moisture of decomposition' during storage or shipment. A further important point that is brought to light is the fact that, what is commonly reported as 'loss in transit' cannot be attributed to loss of 'free moisture' alone. It would include the loss of gas and 'moisture of decomposition' as well, that are generated during biological deterioration from the degenerative breakdown of anhydrous copra.

Heat of Decomposition. It should be relevant at this stage to make reference to another concomitant feature of biological deterioration. Closely associated with the process of deterioration and directly due to the presence of moisture in the copra is the phenomenon of self-heating. With certain materials like hay, cattle manure and many forms of cellular waste material, it is known that temperatures high enough to cause spontaneous ignition may be generated. Though under-dried copra is regarded as somewhat dangerous cargo. (Class 3 in the Suez Canal schedule of dangerous materials) conflicting views have been expressed regarding the real possibility of high enough temperatures being generated to cause spontaneous combustion. Literature records[2] show that the highest temperature recorded in the hold of a ship is only 67°C. The view has been expressed that 'there is no direct connection between spontaneous heating and spontaneous combustion except perhaps that the process of rotting may release some of the contained oil which soaks into the fibre of the bags in which the copra is packed, or alternatively may result in the accumulation of dry copra dust in the material of these bags'. This view implies that copra is not regarded as a readily inflammable material but that the jute fibre of the bags soaked in oil may smoulder, although the temperature is insufficient to ignite the copra. It is further understood that while copra is difficult to ignite, copra dust like fibrous dusts can explode when exposed to a naked flame[3]. It has been pointed out for example that 'the introduction of a hurricane lamp to a copra store would be fraught with danger if there is a suspension of copra dust in ignitable proportions in the air'.

Changes in Physical Characteristics. Whenever the process of deterioration sets in, the chief visible results on the copra may include a superficial or internal discolouration of the meat associated with a breakdown of the tissues. Whilst a slight and superficial discolouration may not have serious consequences, tissue degeneration is always bound to materially affect the character and quality of the product. In extreme cases, the process results in a soft pulpy mass of black rank smelling slimy copra which is riddled with worms and insects. When copra in such a state of extreme decomposition dries out, it invariably yields a mixture of hard congealed and rubbery pieces of a near black colour, embedded in a mass of loose copra dust, containing 'smalls', extraneous dirt, dried fungal mycelia and the remains of insects.

Changes in Analytical Characteristics. Copra of the best quality would generally have a moisture content ranging between 5 and 6 per cent and would yield an oil with a free fatty acid content under 0.1 per cent (calculated as lauric acid). As regards the oil content, this would generally range between 67 and 69 per cent (dry basis) in the fresh and undeteriorated product.

When deterioration sets in, it has been observed that certain significant changes take place which affect the analytical characteristics. Depending on the atmospheric humidity the process of decomposition may add moisture to the copra so that when bad copra is stored under damp conditions in ill-ventilated stores, the quality may easily become progressively worse, resulting in a slimy, dark, matted and evil smelling product. The interesting feature is that under conditions of such deterioration there is besides a steep rise in the free fatty acidity, also a perceptible increase in the percentage oil content of the meat. In other words, as the moulds destroy the tissues, deterioration involves loss of weight and loss of quality in the oil, but strangely enough also an actual increase in the oil percentage.

The plausible explanation for the phenomenon of increased oil percentages with progressive deterioration is that there is to be found in the coconut kernel a definite oil gradient when it is sliced tangentially, parallel to the testa or brown integument. When moulds attack the inside face of copra, the tissues containing the lowest amount of oil are broken down first and removed ultimately in the form of gas and water vapour. The unattacked layers of copra nearer the testa, that remain, which are richer in oil, naturally give higher oil percentages. It should however be mentioned in this context, that though the oil content (when expressed as a percentage) apparently increases, owing to the progressive destruction of the tissues from biological deterioration, yet the actual recovery of oil on a nut basis would be lower. Further, from the commercial point of view it should be remembered that the quality of the oil and also the poonac recovered from deteriorated copra, is inferior so that losses on refinement would naturally be higher.

Factors and Agents of Copra Deterioration

The fundamental causes of copra deterioration are many and their various effects are not infrequently superimposed. In the generality of cases the spoilage which may occur before, during or subsequent to drying is generally traceable to gross neglect, insufficient drying, careless methods of preparation in kilns of unsuitable design, or to the practice of blending poor and good copra together. In rare instances, copra can also get inadvertently spoilt as a result of 'sea damage'.

Starting with a given quantity of fresh coconut kernel, it may be said in general, that the quality and quantity of copra ultimately reaching the oil mill would depend on at least four different factors which may be epitomised as follows:—

1. The care exercised in the various stages of drying and preparation of the product.
2. The initial moisture content of the freshly manufactured copra.
3. How the product is handled and treated during bulking, storage and transport.
4. The actual period of time elapsing between the preparation of the copra and the manufacture of oil from it.

Having considered in outline the factors that determine the quality and keeping properties of copra, we could now proceed to consider the principal agents responsible for deterioration itself.

Deterioration due to moisture. Contained or re-absorbed moisture may be regarded as *the* most important single factor that governs the initiation and progress of deterioration. In fact the presence of sufficient moisture is an essential pre-requisite for the progress of the complex hydrolytic chemical processes associated with copra deterioration. It has already been pointed out that the fresh wet coconut meat is a ready target for attack by micro-organisms. Insufficient dryage during preparation leaving a moisture content in excess of 6 or 7 per cent, or inefficient storage in ill-ventilated, damp rooms unprotected from rain, in a stagnant moisture saturated atmosphere also conduce very readily to biological deterioration.

Bacterial fermentation and fungal action on copra always imply the presence of moisture. The intensity of such attacks however would generally vary with the precise moisture content. It is generally reckoned that bacterial activity is greatest at moistures over 10 per cent whereas fungal moulds have been found to be active even at moisture contents below 6 per cent. Regarding insect pests which breed in copra, it is known that they prefer fairly moist, and very mouldy conditions when they can readily feed on intermingled fungal mycelia and spores.

Deterioration due to Mycological Factors. Since the activities of true fungi and bacteria, under practical conditions are closely associated with each other, it would really be superfluous to separate them in a consideration of their influence on the process of deterioration. It should however be mentioned that it is the bacteria (and occasionally yeasts) that break down the cell structure of coconut meat and initiate deterioration owing to their attraction to the sugars in the kernel (and the adhering film of coconut water) which they ferment.

Usually it would take about 6 hours after splitting of the nuts for one to observe the first visible symptom of bacterial infection. Wherever pin-head indentations occur on the meat, bacterial colonies first appear as shiny white specks. In about 8 hours time these small colonies merge into each other and the meat begins to get gummy and later slimy. Ultimately, the slime assumes a viscous consistency with a yeasty smell, and coats the entire inner surface. If the sliming process is allowed to proceed unchecked it generally results in a marked pitting and corrosion of the tissues of the meat. This is usually followed by the appearance and development of moulds which penetrate into the deeper tissues of the meat. At this stage, insect activity may commence, reducing the copra in extreme cases to a pulverized mass with concomitant mite infestation. It could be said that the intensity of mould and insect attack on copra is generally dependent upon the extent to which the cell structure is initially broken down by the bacteria.

Copra containing under 10 per cent of moisture has been observed to be generally free from bacterial action. It could be said that the most favourable conditions for bacterial attack are provided when wet or half dried coconut meat is exposed to cold and humid conditions for long periods. At a relative humidity of over 80 per cent and a temperature not exceeding 30°C it has been found that bacterial slime may commence to show even in four hours, while in eight hours the copra can be irremediably spoilt. Mould attack generally follows within 48 hours of bacterial sliming unless the moisture content is reduced to below 20 per cent within this period. It is known that whilst only a yellow discolouration of the meat results from incipient bacterial invasion, with prolonged activity a permanent and penetrating redness is imparted to the copra on drying. Under typical conditions of biological deterioration it may be said that bacterial activity is generally a precursor of fungoid activity.

Though moisture is undoubtedly the initiator of deterioration it cannot be regarded as the sole factor involved in the growth of moulds because mould activity normally commences only two days after the development of bacterial slime. It is very likely that the sequence of attack by bacteria and specific moulds is determined (apart from other factors) by the appearance of specific degradation products of the complex glycerides, proteins and carbohydrates present in the coconut kernel. Doubtless the humidity of the atmosphere (which controls the rate of drying of the meat) is also indirectly an important factor in the establishment and development of fungoid growths.

It is very commonly observed that under identical conditions, certain types of drying coconut kernel bespecially meat from germinated coconuts) are attacked by fungi earlier than others. In extreme cases even spore formation takes place before the neighbouring meat is attacked. On the basis of what has been mentioned above the likely explanation for this is that in such instances, owing to enzymic decomposition of fats, proteins and carbohydrates of the meat, a superficial medium suitable both in pH (acid range) and available microbial food has been created so that there is spontaneous fungoid activity. Regarding the definite succession of different fungoid growths which may be observed during the deterioration of copra, the phenomenon probably results from the changing pH associated with the increasing acidity of the medium. This may be considered plausible since it is known that different fungoid lipases and esterases (fat splitting enzymes) function under fairly narrow pH ranges. In the case of the ungerminated coconut however the surface of the fresh meat is almost neutral or only faintly acid (pH 6.0 — 6.8) a condition which is known to be favourable for bacterial activity owing to the fact that bacterial lipase has its optimum at pH 7.2 to 9.0.

There are two types of fungi which attack copra under tropical and sub-tropical conditions. They can be categorised as the superficial and penetrating moulds which are confined principally to the genus *Aspergillus*. The former appear on the surface of dry copra and are comparatively innocuous. The latter however destroy and consume the tissues of wet copra and cause considerable loss and depreciation. If deterioration is checked after the penetrating moulds commence their activity, the fungal mycelia dry up, and a dust of high acidity falls off and discoloured copra of high oil content is left owing to the removal of the original surface layer which was least rich in oil. A sample of copra dust has been found to yield an oil with a free fatty acid content as high as 47 per cent. With progressive disintegration of the surface layers of copra into water gas and acid, the oil content of the residual copra would continue to rise to as much as 75-76 per cent which is generally the average oil content of the tissues nearest the brown integument or testa.

The micro-organisms found in association with coconut meat and copra containing various percentages of moisture, have been enumerated by Ward and Cooke[4] and it should be appropriate to make brief reference to this classification:—

A. *Wet and Drying Coconut Meat with* 20-50 *per cent moisture.*

(1) Two bacteria (short rod and long rod — pale yellow).

(2) Penetrating mould Aspergillus niger (black).

(3) Penetrating mould Aspergillus flavus oryzae (yellow brown).

(4) Penetrating mould Rhizopus nigricans (white mould later turning black).

B. *Half dried copra with* 12-20 *per cent moisture.*

The three penetrating moulds mentioned in (A) above.

C. *Insufficiently dried copra with* 8-12 *per cent moisture.*

(1) Penetrating mould Aspergillus tamarii (yellow brown).

(2) Superficial mould Aspergillus glaucus (green).

D. *Dry copra with less than* 8 *per cent moisture.*

(1) Superficial mould Aspergillus glaucus (occasionally).

(2) Superficial mould Aspergillus cinnamomeus (buff to cinnamon).

(3) Superficial mould Penicillium glaucum (green).

E. *Well dried copra with under* 6 *per cent moisture.*

Usually free from even superficial moulds, if the copra is stored in a dry atmosphere.

Though other micro-organisms have been recorded, they would appear to play only a minor role in causing normal copra deterioration.

Deterioration due to Entomological Factors. From what has been discussed already it should be evident that besides bacteria and fungi, insects also contribute appreciably to the deterioration of copra. In this connection, cell degeneration due to the activity of bacteria is known to be a factor of major importance as regards the susceptibility of copra to insect attack. It has been observed that copra which has deteriorated or softened through bacterial sliming has a considerably greater attraction for copra consuming insects than hard well dried copra. 'Red or caramelised copra too has been found to be a special attraction for the majority of these insects. This has been proved by the fact that 'red' copra is attacked first when it is stored adjacent to high grade white copra. It is likely that the degradation products in the caramelised copra serve to attract these insects. One interesting point is that unlike the action of moulds the effect of insect attack in a *great many cases* is that the oil percentage is not impaired because the oil is consumed simultaneously with the tissues.

Apart from quantitative losses in anhydrous copra due to actual consumption, the main objection to the presence of insects in copra is the production of 'dust'. Dust, is the commercial term generally applied to the mixture of fine broken debris and fractured pieces of copra along with any extraneous contaminants in the sample. It should be mentioned that the presence of dust in the shipped product is the common cause of arbitration for price adjustment. It could be said that the ultimate production of copra dust is always due to the depredations and serious decomposition by moulds and insects. Certain insects associated with copra do not actually consume it, but break down the moulds and burrow into the meat to lay their eggs, and in so doing produce a quantity of this dust. A second factor which is conducive to the production of dust is the activity of a small group of insects which (unlike most others found in copra) feed only on the oil and thereby eliminate a great deal of non-fatty solids as a product of disintegration. It should be relevant at this stage to mention that there is the practice of chopping, ramming and compressing copra for purposes of space economy. This inevitably results in the production of 'smalls'. Careless nut splitting too could produce similar results. A much broken-up or fractured copra unlike the product cured from half-nuts obviously exposes a larger surface area to the atmosphere, whereby oxidation, and mould cum insect attack are very much encouraged. Under such conditions too a highly acid dust is rapidly produced.

As a rule, the initial attack on soft copra is made by the larger insects. Later on, as the copra dries out and hardens, mites and ants may proceed to attack the tissues near the brown integument which is richest in oil. In extreme cases of degeneration, the copra may be reduced to a riddled mass of dust, disintegrated debris, and brown testa. This generally happens only when poor quality copra has been kept in storage exposed to insect infestation for very protracted periods of time. It should be pointed out, that not all insects associated with degenerated copra actually devour the meat. A certain class is purely predaceous and this group feeds only on larvae or grubs of other insects (and sometimes their own) as they develop in furrows or channels found in disintegrating coconut meat.

It may be said that the actual quantity of mouldy degenerated copra present in a particular location would normally determine the intensity of insect infestation. In other words, insects would be entirely absent in estate stores or warehouses where well dried good quality copra *alone* is prepared and handled. By world standards, Ceylon copra is undoubtedly good and this would explain why serious trouble resulting from the depredations of insects is not encountered very much in this country. Methods of preparation are satisfactory and the product is rarely kept in storage for very long periods prior to processing or export.

Entomological records from coconut producing countries show that the most prevalent insects in copra are Necrobia rufipes (de Geer), Carpophilus dimidiatus (F), and Ahasverus advena (Waltl). Of course, the less prevalent insects (including cockroaches) are somewhat numerous. Necrobia rufipes, which is known to the trade popularly as the 'copra bug' is principally a warehousing pest. It is a beetle which is mostly attracted to wet mouldy copra.

A consideration of the biology of Necrobia and the other insects associated with copra deterioration, is strictly outside the ambit of this paper.

Experimental Assessment of Losses Through Deterioration

Undoubtedly the importance of the coconut palm as a factor both in the internal and external economy of coconut growing countries is being increasingly realized and much work has been directed in recent years towards the improvement of coconut products. Very useful investigations have been carried out in the past on copra and its by-products but more intensive research is essential and remains to be done. When we consider the varied uses of coconut oil both as a food supplement and its applications in the soap and allied industries, the importance of producing the article in its purest form, will be readily understood, when we appreciate the need for increased returns coupled with a cost reduction of the manufactured product. On the basis of what has been considered so far this could be ruled out as a virtual impossibility unless the raw material itself from which the oil is produced is of the highest possible quality and is processed in its best form.

The preliminary reconnaissance of the theoretical and practical aspects of copra deterioration should no doubt afford some understanding of the constellation of controlling factors involved and the multifarious problems that could militate against the production of the best possible quality of copra. Conditions are not altogether similar in each country, more especially with regard to the types of organisms attacking copra and also the prevailing climatic features. Further, depending on the precise circumstances under which the raw material is handled and processed, losses to the producer and the industry could be heavy and serious, in which case attempts to remedy the condition would obviously be called for.

It is considered pertinent at this stage to attempt with the help of experimentally obtained values to evaluate firstly the extent of these losses and then proceed with a consideration of what attempts and practical measures could be adopted to counter and minimise any losses that are strictly avoidable. The subject itself has received attention and study in some countries in the past, and it is felt that whatever information of value that is available, should be reviewed to advantage for a start.

REVIEW OF PAST WORK

(*A*) In order of publication, the earliest work on the subject appears to be that of WALKER[5] in the PHILIPPINES in 1906. Certain interesting observations have been recorded by him which are noteworthy. Factual information and data however, supporting all the observations reported by him are not available in the publication.

(1) The most important fact brought out by this work is that by far the greatest deterioration which coconut oil undergoes, takes place within the copra itself. 'After the oil has been expressed from the dried meat its change on standing is very slight compared with that which is found in the same time, while it is in the copra'. In other words, most of the free acid and the accompanying bad odour and taste of low-grade commercial coconut oil is produced in the copra itself before the oil has been expressed.

(2) From the practical point of view the most significant point reported in the paper is that copra containing 9.09 per cent of moisture was found to be attacked by moulds with the consequent production of free acid and colouring matter and also a loss in weight of oil. On the other hand, a sample containing 4.76 per cent of moisture was found to remain practically unchanged on standing under conditions which precluded the re-absorption of moisture. The relevant experimental data are given in Table III below. The results are self-explanatory and need no discussion.

TABLE III

Weight losses relative to Moisture Content of Copra

1		2	3	4
SAMPLE		*No.* 1 (*Control*)	*No.* 2	*No.* 3
% Moisture	..	0.00	4.76	9.09
Weight of DRY COPRA (Gms.)	At start ..	10.00	10.00	10.00
	After 2 weeks ..	10.00	9.99	9.70
Total loss in weight in 2 weeks (Gms.)	..	0.00	0.01	0.30
Weight of OIL (Gms.)	At start ..	6.79	6.79	6.79
	After 2 weeks ..	6.79	—	6.61
Loss of Oil	..	0.00	trace	0.18
Loss of substances other than oil (by difference)	..	0.00	trace	0.12
% Free ACID	At start ..	0.15	0.15	0.15
	After 2 weeks ..	0.15	0.18	8.7

(*B*) Next in order, reference should be made to the work of BRILL, PARKER and YATES[4] also in the PHILIPPINES, in 1917. These workers have recorded some very valuable quantitative data principally on the mycological aspects of copra deterioration. Analytical and botanical data relative to losses in copra and oil due to faulty production of copra have been brought out in the paper with suggestions for means of improvement.

(1) They maintain that when the bulk of the copra produced in a country is inadequately dried, the gross financial loss to producers is severe. They point out that this financial loss is incurred firstly because freight has to be paid on the contained superfluous moisture which can only cause deterioration with concomitant impairment of quality and depreciation in value.

(2) Losses in weight which occur during storage and shipment of poorly prepared copra containing excess moisture, are not due to the evaporation of water alone but also the very material losses of copra and oil.

(3) Laboratory experiments conducted on copra under moisture conditions most favourable for mould growth (10-20 per cent), have shown losses of 25 per cent in total oil content. The results obtained at room temperature on six samples, which represent the losses (in 15 days) due to the combined action of green, brown, black and white moulds are shown in Table IV.

TABLE IV

Effect of the four common moulds — green, brown, black and white — growing together on copra

1	2	3		4
Sample	*Weight of copra taken (Gms.)*	*Loss of OIL (in 15 days)*		*% Acidity as Oleic. (after mould action)*
		Gms.	*As % of oil in copra before mould action*	
1	17.10	1.2700	24.9	15.6
2	17.50	1.3145	25.2	12.4
3	16.62	1.2042	24.3	13.0
4	15.96	1.0404	23.8	9.0
5	16.14	1.3516	28.1	11.4
6	84.20	6.4306	25.6	10.0
Mean	27.92	2.1019	25.3	11.9

(*NOTE* — Acidity of oil expressed from fresh coconut meat is about 0.2 per cent calculated as oleic.)

(4) With a recognition of the fact that a loss in oil content must be associated with a loss in weight of the copra, an experiment was carried out to determine this factor when commercial copra from various provinces is stored in bodegas (stores). No details of the experiment are reported but the average percentage losses in weight computed from the recorded data are presented in Table V.

TABLE V

Loss in weight of copra from various provinces when stored in commercial bodegas

1	2	3	4
Place of Production	*Average days of Storage*	*% Loss in Weight (weighted averages)*	*No. of Samples*
Albay Province	20	5.91	3
Camarines Province	24	3.65	4
Capiz Province	24	6.70	4
Laguna Province	20	9.79	10
Pangasinan Province	23	7.38	7
Samar Province	24	1.54	2
Sorsogon Province	20	4.70	6
Surigao Province	23	5.50	1
Tayabas Province	23	9.07	19
9 Provinces	22	5.96	56 (Samples)

The results merely indicate that on the basis of an examination of 56 samples from nine provinces in the Philippines, an average loss of 5.96 per-cent occurred in 22 days. The experiment however does not afford an evaluation of the respective percentages of this total loss represented by moisture, oil and anhydrous copra.

(5) That a further loss in weight of copra takes place on shipboard has been recognised. This loss has been estimated to range between 3 and 6 per-cent, depending primarily upon the length of time of storage prior to shipment. This is essentially an estimate made by copra dealers which is not based on actual experiments.

(6) The loss due to paying freight on loss of weight alone is reckoned to be considerable, and even when freight rates are normal would be too large to be ignored. When the product is underdried there results not only an unnecessary expense of handling an excessive amount of water but also consequent loss of quantity and quality of oil resulting from mould action.

(7) Though there is some sort of price discrimination for the poor and higher grade product, monetary losses have to be borne principally by the producer since the buyer always adjusts his price to allow for extra moisture and extra handling and transportation costs. In general the production of poor quality copra has been considered an economic loss to the Philippine Islands.

(8) On the basis of 26 determinations on Laguna copra it has been shown that where the temperature of the atmosphere was only 29°C and the percentage of carbon-dioxide in it less than 0.10 per-cent, the average temperature in the centre of a pile of stored commercial copra was 42.7°C. The average carbon-dioxide content in the air over this copra has been recorded as 0.6 per-cent. The inference is therefore drawn that the losses incident to storage and shipment of copra over periods extending for 2-4 months are not due entirely to the evaporation of water. Slow combustion obviously takes place with the formation of carbon-dioxide and water, necessarily at the expense of meat and oil.

(9) Well dried copra was never found to become hot or to evolve carbon-dioxide when piled in storage. It is inferred that combustion is due to the presence of higher quantities of moisture followed by mould action.

(10) Various factors enter into the analysis of copra from the point of view of oil loss. When the total weight of the sample is lowered through micro-organic action it should be remembered that both meat and oil are simultaneously destroyed and removed. If the weight of fibre destroyed is not taken into account, then the apparent loss in oil only could be estimated. In other words, results calculated on the basis of the moulded sample alone for demonstrating the quantity of oil decomposed would be worthless. It is obviously necessary therefore to know quantitatively the total weight of oil in the original undeteriorated material, if the percentage of total loss is to be computed, from the actual weight of oil before and after deterioration. The experimental data obtained on five samples of copra which are given in Table VI, show the calculated figures for the apparent and true losses in oil.

TABLE VI

Oil losses in Copra calculated on oil percentages and on total oil content

1		2					
SAMPLE No.		1	2	3	4	5	6
Weight of DRY COPRA (gms.)	Before mould action	13.5802	11.7834	13.2477	16.1955	13.3213	13.6256
	After mould action	11.8890	10.2104	11.8089	14.4030	11.9880	12.0599
Tot. loss in wt. after mould action		1.6912	1.5730	1.4388	1.7925	1.3333	1.5657
% OIL in COPRA (DRY weight)	Before mould action	67.5	67.5	66.8	66.8	66.8	67.1
	After mould action (Calc.)	53.6	54.6	49.6	47.1	46.7	50.3
Apparent loss of oil (by diff.) %		13.9	12.9	17.2	19.7	20.1	16.8
Total weight of OIL (gms.)	Before mould action (Calc.)	9.1645	7.9540	8.8386	10.8155	8.8744	9.1294
	After mould action (Calc.)	6.3465	5.5846	5.8570	6.7880	5.6010	6.0354
TRUE LOSS OF OIL	Grammes	2.8180	2.3694	2.9816	4.0305	3.2734	3.0940
	Per-Cent	30.7	29.8	33.7	37.2	36.8	33.6

The results in the tabulation show conclusively that the true loss of oil is very much greater than the apparent.

(11) When fresh coconut meat is exposed to the air various fungi make their appearance and as the moisture content of the meat becomes less, these fungi are succeeded by others. Certain fungi always appeared on the fresh meat whilst others appeared only on fairly dry copra. The life history of each of the more important moulds was studied to determine whether the effect on the oil caused by the different species of fungus might not vary. The results secured in the

experiments are summarised in Table VII and show the effects of the four principal copra moulds on the quantity and free acidity of the oil present.

TABLE VII

Effect of Mould action on the quantity and free acidity of oil in Copra

1	2				3			
SAMPLE	*Mould acting for 10 days upon Shredded Meat*				*Mould acting for 30 days upon Un-shredded Meat*			
	White Mould (Rhizopus sp.)		*Black Mould (Aspergillus niger)*		*Brown Mould (Aspergillus flavus)*		*Green Mould (Penicillium glaucum)*	
	Oil loss %	*% F.f.a. (as Oleic)*	*Oil loss %*	*% F.f.a. (as Oleic)*	*Oil loss %*	*% F.f.a. (as Oleic)*	*Oil loss %*	*% F.f.a. (as Oleic)*
1	43.1	21.0	51.3	9.5	30.7	6.8	6.20	1.2
2	36.4	19.8	23.0	8.0	29.8	5.1	0.69	1.0
3	41.0	26.6	13.0	2.9	33.7	7.7	0.87	0.9
4	—	—	—	—	37.2	7.2	0.54	0.8
5	—	—	—	—	36.8	6.5	—	—
6	—	—	—	—	37.0	7.0	—	—
7	—	—	—	—	40.3	9.1	—	—
*MEAN	40.2	22.5	29.1	6.8	35.1	7.1	0.6	1.0

The results show that where green mould alone is present the loss of oil is negligible, and the production of free acid is extremely low. The presence of the mould however would indicate a higher moisture content in the copra, than in the product where no mould is present.

It is generally concluded that a copra dealer may expect an oil loss ranging between 30 and 40 per-cent upon all copra which contains sufficient moisture to enable brown mould to grow. A further increase of moisture content would make very little difference as brown mould will then grow in association with black mould with oil losses of the same order.

(12) Experiments to determine the critical moisture content for the growth of different moulds revealed the following optimum ranges for their activity:—

Rhizopus sp. (white mould) — 40 to 50 per-cent.
Aspergillus niger (black) — 18 to 20 per-cent. (minimum 12 per-cent).
Aspergillus flavus (brown) — 7 to 8 per-cent.
Penicillium glaucum (green) — 5 to 7 per-cent.

(13) *Aspergillus flavus* generally plays the most important part in the destruction of the oil in copra. Since it occurs in copra with a moisture content lower than the average for Philippine copra, it is responsible for the destruction of a very high percentage of the copra of the Islands.

(C) The work carried out by BLACKIE[7] in FIJI in 1930, provides some useful quantitative information. On the basis of certain mycological investigations an attempt has been made to estimate losses through deterioration from mould action. The complexity of the chemical problems connected with the decomposition of copra, chiefly by mould action, has also been indicated.

(1) The growth of two moulds Aspergillus flavus (brown) and Aspergillus niger (black) on grated coconut meat adjusted to 10 per-cent moisture content, was studied. Quantitative observations were made over a period of four weeks to estimate the apparent and actual losses in oil: loss of anhydrous copra and changes in free acidity. Mean figures obtained for the two moulds are presented in Table VIII.

TABLE VIII

Losses in Copra resulting from Mould Action

1	2	3	4	5
PERIOD	*ONE WEEK*	*TWO WEEKS*	*THREE WEEKS*	*FOUR WEEKS*
% Loss anhydrous Copra	3.4	9.9	13.5	16.1
% Apparent loss OIL	9.6	13.3	20.3	20.8
% Actual loss OIL	11.6	18.7	26.7	28.4
% Obscured loss OIL	2.0	5.4	6.5	7.6
% Free Acid (as Oleic)	5.2	5.3	4.5	3.4
% Oil (dry basis) control sample	68.1	68.1	68.0	68.2
% Free Acid (as oleic) control sample	0.3	0.3	0.5	0.4

N.B. — The figures for loss of oil are calculated on anhydrous copra.

At Commencement of Experiment (Control Sample)

% Oil (dry basis) — 68.2
% Free Acid (as oleic) — 0 .3

The results in the above table are self explanatory and need no further discussion.

In considering the experiment it will be clearly understood that the results obtained could not be compared in any quantitative way with the results that would be obtained with copra made and stored under commercial conditions. The experiment was designed to obtain the maximum oil loss by providing optimum conditions for mould growth.

(2) Concurrently with the above a second experiment was carried out without employing selected species of mould. The object of this experiment was to infect shredded copra with spores normally present in copra stores, by exposing the meat in petri-dishes for 3 hours in two bulk copra stores. At the end of 28 days, analyses were performed as before.

It was found that the actual loss of oil was relatively much less than in the previous experiment and averaged 4.4 per-cent. The average loss in anhydrous copra too was much less amounting to only 3.9 per-cent. The free fatty acid however was high, the average figure being 8.3 per-cent.

(3) A third experiment was carried out on 86 pounds of copra, carelessly dried down to 10 per-cent moisture content on an open Fijian 'Vata'. The product was then stored for 14 days under unsatisfactory conditions. In this period the total loss of anhydrous copra was found to be 12.4 per-cent, with an actual loss of contained oil amounting to 8.2 per-cent. The percentage oil content

(dry basis) of the copra declined from 67.6 to 59.4 per-cent. The acidity of the contained oil rose from 0.2 to 8.5 per-cent (calc. as oleic). The brown mould (Asp. flavus) which appeared in quantity on the fifth day appeared to cause most damage. Such attack was found to be assisted by copra beetles penetrating into the copra in the mouldy zones. The experiment further appeared to indicate that the main loss takes place not on the 'Vata' itself but during storage before the moisture content falls below 6 per-cent. If this is correct, the view is expressed that a much greater loss of copra than the 12.4 per-cent obtained in this experiment appears to be possible in the wetter districts of the country.

(4) It is estimated that the total production of copra in Fiji in 1926 was 27,868 tons. If the assumption is made that all this suffered deterioration from mould action to the extent of 12.4 per-cent, then the loss to producers would be at least £70,974 at the then ruling price of £18 per ton. This loss would be even greater in the wetter districts of the Group.

(*D*) In conjunction with certain mycological studies, the question whether a detailed biological survey would be justified in order to ascertain the extent of the loss to the industry caused by insects and moulds (during the period between its preparation and the manufacture of oil from it) has been considered on the basis of preliminary enquiries in a publication by PASSMORE[8] in LONDON in 1931. The following useful observations principally relating to the attitude of buyers and manufacturers towards the problem have been made:—

(1) British manufacturers of edible coconut oil require clean, dry copra of low acidity. Where the oil is used for the manufacture of low-grade soap, the oil content of the product is the only material consideration.

(2) The buyer does not consider the development of moulds on copra in any way helpful or advantageous in the milling process, as believed in some quarters.

(3) Where shipments are attacked by contemporary and subsequent mould, insect and mite infestation, the loss of copra by actual consumption is reckoned, to be considerable, judging from the quantity of 'Dust' produced which is a common cause of arbitration for price adjustment.

(4) Cargoes loaded in a damp and mouldy condition dry out sufficiently in transit to Europe to render the moulds inactive when they reach the buyer. It is rarely that large stocks would deteriorate after purchase.

(5) As long as sufficient good quality copra is produced to meet their requirements, manufacturers are not directly affected by the problem of losses resulting from deterioration. They pay for delivered weight only and if the copra is not up to standard an allowance is claimed by arbitration. Where the product is above standard then no more than the agreed price can be demanded by the seller.

(6) In a nut-shell, even if the expressed oil has to be subjected to expensive refining processes, to eliminate free fatty acids, smell and discolouration, to render the oil fit for edible purposes, material losses resulting from biological deterioration do not affect the manufacturer from the monetary angle. The price he pays rests entirely on the basis of quantity and quality at the time of purchase.

(*E*) In order of publication, reference should finally be made to the work of COOKE[9] in MALAYA in 1939. The principal value of this work lies in the fact that very useful quantitative data relating to losses have been obtained on fair size samples weighing several pounds, on different pre-determined grades of Straits copra.

(1) It is estimated that the time elapsing between production and milling of copra could vary anything between 35 and 229 days, under conditions prevailing in the Straits Settlements. The period would be principally determined by locality, problems of collection and local transport, seasonal variation in crop, freight charge fluctuations, available cargo space, and the state of the copra market.

Table IX provides details of a rough estimate of the time taken to pass copra from the producer in Malaya to the miller in Europe.

TABLE IX

Approximate times for various operations which may occur between Producing and Milling Small-holders' Copra

1	2
OPERATION	*TIME (Days)*
House Storage	1 to 7
Shophouse Storage	0 „ 7
Local Dealers' Stores	0 „ 7
Road, River or Coastal Transport	1 „ 4
Warehousing at Export Centre	0 „ 150
Ocean Shipment	30 „ 40
Bulk Storage before Milling	3 „ 14
Total	35 to 229

(2) The observation has been made that the bulked copra which ultimately arrives at the export centres (Singapore, Penang and Port Swettenham) from different producing centres is variously dry. 'It exhibits different features and degrees of deterioration depending on the treatment accorded to the product and the effect of weather conditions on production, storage and shipment'.

(3) Two storage trials were carried out in order to ascertain the extent of loss which occurs when six different types of copra produced in Malaya are stored for a fair period of time (2 months) under typical conditions of storage. The six different types selected for the experiment are shown in Table X. They are regarded to be representative of the different types of copra produced in Malaya.

TABLE X

Types of Copra used in Storage Trials

1	2	3
LOT	*INITIAL CONDITION*	*MOISTURE CONTENT (Per-cent)*
W 1	Dry smooth white copra	about 8
W 2	Fairly dry white copra	9 to 12
W 3	Half dried 'raw' white copra	about 20
R 1	Dry unscorched 'red' copra	about 8
R 2	Fairly dry 'red' copra	9 to 12
R 3	Half dried 'raw red' copra	about 20

The six lots described in Table X were each prepared from 100 coconuts collected from the same estate. The 'red' copra was produced by allowing bacterial decomposition to be initiated prior to drying and to continue to develop subsequently through deliberate carelessness during drying.

The different lots of copra prepared in this fashion were all kept under two methods of storage. for a period of 2 months. In one, Trial A, the six lots were sent immediately after manufacture for bulk storage in a Singapore warehouse with copra of corresponding qualities. (Continuous Warm Storage). In the other, Trial B, the six lots were initially stored for 14 days in a cool place in individual isolated bags (Cool Storage). Then they were warehoused exactly as in the first trial. Trial A is reckoned to roughly simulate the conditions accorded to the copra by large producers and Trial B those of small producers. The various lots of copra were each examined, weighed, sampled and analysed before during and after storage. At the end of the period of storage the amount of 'smalls' and 'dust' associated with each lot was also ascertained. A qualitative assessment of the copra was also made at the close of the experiment, by a Singapore merchant. The comparative results of the two trials are summarised in Tables XI to XV.

TABLE XI

Total loss in weight during storage

1	2			3		
LOT	*TRIAL A CONTINUOUS WARM STORAGE*			*TRIAL B COOL AND WARM STORAGE*		
	Original weight (lbs.)	*Loss in weight (lbs.)*	*Loss %*	*Original weight (lbs.)*	*Loss in weight (lbs.)*	*Loss %*
W 1	63.75	1.50	2.3	56.25	3.25	5.8
W 2	68.75	5.50	8.0	64.25	6.00	9.3
W 3	78.75	18.75	23.8	79.75	20.50	25.7
R 1	60.50	3.25	5.3	58.50	3.25	5.6
R 2	67.50	6.00	8.9	64.25	10.00	15.6
R 3	78.50	17.00	21.6	74.50	20.25	27.2

The total loss in weight in storage includes not only loss of free moisture, but also loss of actual dry copra through decomposition. This loss is expressed in Table XI as a percentage of the original weight of copra including contained moisture. Recalculated data showing actual losses of anhydrous copra are shown in Table XII.

TABLE XII

Loss of Actual Copra during Preparation and Storage

1	2				3				
LOT	*TRIAL A CONTINUOUS WARM STORAGE*				*TRIAL B COOL AND WARM STORAGE*				
	Original Dry Weight (lbs.)	*Preparation loss (lbs.)*	*Storage loss (lbs.)*	*Total loss %*	*Original Dry Weight (lbs.)*	*Preparation loss (lbs.)*	*Cool Storage loss (lbs.)*	*Warm Storage loss (lbs.)*	*Total loss %*
W 1	59.25	nil	nil	nil	52.00	nil	0.50	1.50	3.8
W 2	61.75	nil	1.75	2.8	56.50	nil	nil	1.50	2.6
W 3	63.25	nil	6.00	9.5	65.00	nil	6.75	2.25	13.9
R 1	55.25	1.50	0.25	3.2	55.25	1.50	2.00	1.00	8.1
R 2	59.25	1.50	0.25	3.0	58.25	1.50	5.25	1.25	13.7
R 3	61.25	1.50	2.50	6.5	58.50	1.50	5.25	2.00	15.0

It is perhaps surprising that lot W 3 of Trial A showed a greater loss than lot R 3 of the same trial. This is explained by the fact that the smoke which readily adheres to the surface of slimy 'red' copra provides a temporary check to bacterial deterioration and insect attack during the short period before warehouse drying. In Trial B however, where there is prolonged cool storage before warehousing, the agents of deterioration are able to operate freely once the protective smoky film has been broken down.

The extensive deterioration and breakdown which has occurred in lots W 3 and R 3 (Trial B). should be noted. It is maintained that it is possible with such copra to get losses even up to 99 per-cent, if the product is maintained continuously in a wet condition. Only fragments of brown testa may be ultimately left after sustained insect attack and progressive decay.

TABLE XIII

Reduction of Copra to 'Smalls' and 'Dust'

1	2				3			
LOT	*TRIAL A CONTINUOUS WARM STORAGE*				*TRIAL B COOL AND WARM STORAGE*			
	Original Dry Weight (lbs.)	*'Smalls' (lbs.)*	*'Dust' (lbs.)*	*% Spoilage*	*Original Dry Weight (lbs.)*	*'Smalls' (lbs.)*	*'Dust' (lbs.)*	*% Spoilage*
W 1	59.25	nil	nil	nil	52.00	0.75	nil	1.4
W 2	61.75	0.25	nil	0.4	56.50	0.75	0.25	1.8
W 3	63.25	0.75	0.25	1.6	65.00	10.25	0.75	16.9
R 1	55.25	nil	nil	nil	55.25	1.00	nil	1.8
R 2	59.25	nil	nil	nil	58.25	0.50	0.25	1.3
R 3	61.25	0.75	0.25	1.6	58.50	11.75	0.75	21.3

In Malaya any 'smalls' and 'dust' are included and sold as copra, but their presence in any quantity usually creates a serious problem for the miller. Lots W 3 and R 3 in Trial B, (Table XIII), have given results representing the highest percentage spoilage resulting from the production of 'smalls' and 'dust'. Seriously deteriorated copra such as these usually suffer further size reduction during shipment and transport to oil mills so that a larger surface is exposed to the agents of deterioration. It is maintained that losses of small pieces and dust would readily occur when the material is transported loose in conveyors.

TABLE XIV

Free Acidity of Oil and Discolouration of Copra on Storage

1	2			3	
LOT	*% Acidity calculated as Lauric*			*Average Extent of Discolouration*	
	TRIAL A	*TRIAL B*		*TRIAL A*	*TRIAL B*
	After 2 months Continuous Warm Storage	*After Cool Storage only (14 days)*	*After Cool and Warm Storage (2 months)*	*Warm Storage*	*Cool and Warm Storage*
W 1	0.17	0.11	0.30	All White	One-third
W 2	0.22	0.16	0.32	One-third	One-half
W 3	2.61	0.81	3.11	Three-quarters	Total
R 1	0.25	0.17	0.47	One-sixth	One-third
R 2	0.58	0.15	0.39	One-quarter	One-half
R 3	2.20	0.40	6.12	Three-quarters	Total

It will be seen from Table XIV that serious development of acidity does not take place during the period of cool storage when the loss of copra is greatest — (Lots W 3, R 1, R 2 and R 3 of Trial B, Table XII). Regarding discolouration, the extent was found to be very variable from piece to piece. In some it was found to be localized, whereas in others discolouration was complete. An approximate average estimate alone is given in Table XIV.

Finally in Table XV, the comparative values of the various types of copra derived from the same theoretical amounts of fresh coconut meat are given. The calculations have been based on, the actual copra losses scheduled in Table XII, the ultimate quality of the material (whether f.m.s., f.m., or sub-grade), and the following prices of copra per picul:—

	Per Picul (Dollars)
Estate Copra (shipped direct)	3.40
Straits f.m.s. (fair, merchantable, sundried) copra ..	3.30
Straits f.m. (fair, merchantable)copra	3.00
Sub-grade copra	2.70

TABLE XV

Relative Market Values of the Produce obtained from the same Theoretical Weight of Coconut Meat

1	2				3			
	TRIAL A Continuous Warm Storage				*TRIAL B Cool and Warm Storage*			
LOT	*Final Dry Weight (piculs)*	*Price of Copra/ picul (Dollars)*	*Value of Copra (Dollars)*	*Drop in value as % of value of best grade*	*Final Dry Weight (piculs)*	*Price of Copra/ picul (Dollars)*	*Value of Copra (Dollars)*	*Drop in value as % of value of best grade*
W 1	100	3.40	340.00	—	96.2	3.30	318.00	6.5
W 2	97.2	3.30	321.00	5.6	97.4	3.30	321.00	5.6
W 3	90.5	3.00	271.50	20.1	86.1	2.70	232.00	31.8
R 1	96.8	3.30	319.00	6.2	91.9	3.00	275.70	18.9
R 2	97.0	3.00	291.00	14.4	86.3	3.00	258.90	23.9
R 3	93.5	3.00	280.50	17.5	85.0	2.70	229.00	32.6

The experiment indeed provides some very valuable factual information. It clearly shows that within a period of 2 months the monetary losses to the industry resulting from deterioration could range between 5 and 33 per-cent of the value of the best grade of copra produced in the experiment. Further, it should be noted that these losses should be regarded as being 'strictly avoidable' since they resulted from careless methods of preparation coupled with unsuitable conditions of storage, under which samples W_2 To R_3 (Trial A) and W_1 to R_3 (Trial B) were produced. The extent of the losses in each case being obviously determined by the precise conditions of the experiment.

A further observation of value is that under conditions of serious deterioration the individual pieces of copra readily break down to yield appreciable quantities of 'smalls' and 'dust'.

PRESENT WORK

Ceylon copra has an undoubted reputation for quality, and the commercial product is indeed superior to that produced in most other coconut growing countries. The standard Ceylon Copra kiln which is generally used on estates has well known merits being easily adaptable for use on large plantations as well as small village holdings. Further, the drying procedure generally followed embodies adequate safeguards to minimise the production of inferior copra. There are three recognized grades of estate copra (Nos. 1, 2 and 3) produced in Ceylon, and as a rule if the sequence of operations in the curing procedure are carefully carried out, then the yield of the best quality (viz. Estate No. 1) could easily exceed 90 per-cent. Typical sorting figures obtained at Bandirippuwa Estate (Coconut Research Institute) have been found to average 94.5 per-cent for No. 1, 4.5 per-cent for No. 2 and 1.0 per-cent for No. 3 estate copra.

The bulk of the copra exported from Ceylon is of the well-dried edible grade, and the markets are principally India and Pakistan. As the distances involved are not very great, the time elapsing between production and delivery at destination are not usually protracted. Any losses from deterioration during this period would therefore be somewhat insignificant, and at any rate not serious. In domestic trade too, processed copra is generally milled without delay, within a few days or weeks of manufacture. When these facts are borne in mind it could be readily appreciated why no research investigations have so far been initiated in this country to estimate economic losses to the producer which could result from the deterioration of under- dried copra. For the first time certain studies have been carried out on this subject by the Coconut Research Institute (Ceylon) at the request of the Food and Agriculture Organization of the United Nations.

Scope and Methods. At the outset it should be pointed out that the present studies should be regarded as preliminary in nature carried out with the principal objective of obtaining adequate factual data that would substantiate and supplement some of the more important observations that have been reported by previous workers. In fact, the usefulness of some of the available information may be discounted owing to the fact that a factual foundation is lacking. To some extent the present work has added value since the results have been obtained under conditions (especially climate) which would not altogether coincide with those of previous investigations. Since the emphasis of most of the previous work has been on the mycological factors of deterioration, the present studies have been focussed principally on the quantitative aspects of the degenerative losses involved in the process of copra deterioration. Whilst, the longest period over which records and observations have been kept in past studies is only two months, the observational period in the present work is six months. During this period, analytical checks have been made on samples of copra dried to different initial moisture contents, which were subsequently kept under satisfactory and unsatisfactory conditions of storage.

Experimental Details. The drying practice employed in the standard Ceylon Kiln would involve ten distinct stages from the time the nuts are split on the barbecue until the dried copra is removed for storage. These ten stages would correspond not only to different operational changes but also to various degrees of dehydration of the kernel. The sequence of operations and the approximate moisture contents corresponding to these ten stages are shown in Table XVI. Since the principal purpose of the experiment is to assess deterioration losses in relation to different moisture contents, it was deemed appropriate that samples used for the experiment should be representative of the ten distinct operational stages outlined in Table XVI.

TABLE XVI

Moisture contents of samples used for experiment in relation to stages in curing procedure in Ceylon Kiln

1	2	3	4
STAGE	*Operation in Drying Procedure*	*No. of hours since splitting*	*% Moisture*
1	On Splitting	nil	43.80
2	After Sundrying	10	33.85
3	„ First Firing	19	22.42
4	„ Second „	34	12.50
5	„ Third „	43	11.27
6	„ Fourth „	58	8.97
7	„ Fifth „	67	7.76
8	„ Sixth „	82	7.11
9	„ Seventh „	91	6.84
10	„ Eighth „	106	6.06

Three thousand typical estate coconuts drawn from the 4th Crop (1959) at Bandirippuwa Estate were processed in the form of half-nuts for the experiment in strict conformity with the operational schedule outlined in Leaflet No. 15 of the Coconut Research Institute, after seasoning on the field for a period of 4 weeks. Samples were drawn at each of the ten stages of processing, and the cups were looped together in different lots and then hung up in three different types of storage as follows:—

(A) *Air-Conditioned Room* (*Stage* 10 *only*)

(1) Four *weighed* loops with 30 cups each (expressly used for quadruplicate weighings at pre-determined intervals).

(2) Two loops with 50 cups each (sampled at intervals for duplicate chemical analyses).

(B) *Well Ventilated Estate Store* (*All Stages* 1 *to* 10)

(1) Forty *weighed* loops in all, each with 30 cups. Four loops (for quadruplicate weighings) drawn from each of the stages 1 to 10.

(2) Twenty loops in all with 50 cups in each. Two loops (for duplicate chemical analyses) drawn from each of the stages 1 to 10.

(C) *Poorly Ventilated Estate Store* (*All Stages* 1 *to* 10)

(1) Forty loops in all exactly as in B (1).

(2) Twenty loops in all exactly as in B (2).

TABLE XVII

(*A*) Experimental Results from Storage Trials in Air-Conditioned Room

(Well-Dried, GOOD QUALITY COPRA alone from Stage 10 was used)

1	2	3	4		5					6	7	8		
					OIL IN COPRA							*LOSSES expressed as % of original Anhydrous weight taken for experiment*		
PERIOD since Commencement of Experiment (weeks)	*% MOISTURE*	*ANHYDROUS WEIGHT of COPRA (Gms.)*	*TOTAL LOSS of ANHYDROUS COPRA over original*		*% Oil (Wet basis)*	*% Oil (Dry basis)*	*Total weight of oil in Anhydrous COPRA (Gms.)*	*TRUE LOSS IN OIL in terms of oil present in original weight of ANHYDROUS COPRA*		*% Free Fatty Acids in Pressed Oil (as lauric)*	*COLOUR on Lovibond scale of Pressed and Filtered Oil*	*OIL*	*OIL-FREE MEAT (by difference)*	*TOTAL ANHYDROUS COPRA*
			Gms.	*Per-cent*				*Gms.*	*Per-cent*					
START	6.06	2,601	—	—	64.2	68.3	1,776	—	—	0.06	3	—	—	—
2 ..	5.29	2,591	10	0.38	64.7	68.3	1,770	6	0.34	0.06	3	0.23	0.15	0.38
4 ..	4.56	2,588	13	0.50	65.2	68.3	1,768	8	0.45	0.06	4	0.31	0.19	0.50
6 ..	4.91	2,586	15	0.58	64.9	68.3	1,766	10	0.56	0.11	4	0.38	0.20	0.58
8 to 22	NO LOSSES IN ANHYDROUS WEIGHT — NO SAMPLES ANALYSED													
24 ..	3.08	2,576	25	0.96	65.9	68.0	1,752	24	1.35	0.12	6	0.92	0.04	0.96

NOTE — (1) No visible mould action evident, except for a slight white 'bloom' on the brown testa, which first made its appearance after 12 weeks of storage.

(2) The experiment is being continued.

TABLE XVIII

Experimental Results from Storage Trials in Well and Poorly Ventilated Stores

	1					2				
	(B) WELL VENTILATED STORE					*(C) POORLY VENTILATED STORE*				
PERIOD (Weeks)	*% Moisture*	*ANHYDROUS WEIGHT of COPRA (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original %*	*% Free Fatty Acids (as lauric)*	*% Moisture*	*ANHYDROUS WEIGHT of COPRA (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original %*	*% Free Fatty Acids (as lauric)*
STAGE — 1										
START	43.8	2,189	—	—	—	43.8	2,145	—	—	—
2 ..	12.2	2,136	53	2.4	—	13.2	2,066	79	3.7	—
3 ..	6.6	2,057	132	6.0	4.7	8.4	1,985	160	7.5	—
10 ..	11.3	1,845	344	15.7	4.7	6.2	1,932	213	9.9	5.0
15 ..	6.4	1,794	395	18.0	4.7	7.4	1,758	387	18.0	8.2
17 ..	5.9	1,743	446	20.4	4.4	7.2	1,713	432	20.1	7.8
21 ..	5.4	1,686	503	23.0	4.1	7.1	1,586	559	26.1	7.3
STAGE — 2										
START	33.8	2,491	—	—	—	33.8	2,431	—	—	—
2 ..	16.6	2,238	253	10.2	—	15.7	2,250	181	7.4	—
3 ..	12.4	2,029	462	18.5	4.4	11.1	2,069	362	14.9	—
10 ..	9.7	1,951	540	21.7	8.7	7.6	2,056	375	15.4	6.5
15 ..	7.0	1,855	636	25.5	6.0	8.2	1,926	505	20.8	6.6
17 ..	6.2	1,803	688	27.6	6.6	7.4	1,894	537	22.1	9.3
21 ..	5.3	1,745	746	29.9	7.2	6.6	1,822	609	25.1	11.9
STAGE — 3										
START	22.4	2,548	—	—	—	22.4	2,471	—	—	—
2 ..	10.5	2,401	147	5.8	—	13.4	2,326	145	5.9	—
3 ..	9.3	2,205	343	13.5	2.0	11.2	2,182	289	11.7	—
10 ..	10.0	1,968	580	22.8	3.8	5.1	2,142	329	13.3	4.0
15 ..	7.4	1,888	660	25.9	3.7	7.2	1,996	475	19.2	4.7
17 ..	6.7	1,851	697	27.4	3.0	6.6	1,969	502	20.3	6.1
21 ..	6.1	1,797	751	29.5	2.2	6.0	1,922	549	22.2	7.5
STAGE — 4										
START	12.5	2,305	—	—	—	12.5	2,363	—	—	—
2 ..	8.5	2,240	65	2.8	—	7.7	2,329	34	1.4	—
3 ..	8.0	2,204	101	4.4	0.6	7.2	2,295	68	2.9	—
10 ..	9.2	2,062	243	10.5	1.1	6.0	2,279	84	3.6	1.2
15 ..	6.8	2,040	265	11.5	1.4	5.9	2,218	145	6.1	2.1
17 ..	6.3	2,026	279	12.1	1.6	5.4	2,211	152	6.4	2.0
21 ..	5.8	1,996	309	13.4	1.7	5.0	2,176	187	7.9	1.8
STAGE — 5										
START	11.3	2,460	—	—	—	11.3	2,359	—	—	—
2 ..	7.8	2,432	28	1.1	—	8.2	2,338	21	0.9	—
3 ..	7.4	2,405	55	2.2	0.6	7.2	2,317	42	1.8	—
10 ..	12.2	2,344	116	4.7	1.2	6.0	2,295	64	2.7	1.2
15 ..	7.2	2,282	178	7.2	1.5	6.2	2,214	145	6.1	1.0
17 ..	6.3	2,269	191	7.8	1.2	5.5	2,197	162	6.9	1.5
21 ..	5.4	2,256	204	8.3	0.8	4.9	2,157	202	8.6	1.9

TABLE XIX

Experimental Results from Storage Trials in Well and Poorly Ventilated Stores

	1					2				
	(B) WELL VENTILATED STORE					*(C) POORLY VENTILATED STORE*				
PERIOD (Weeks)	*% Moisture*	*ANHYDROUS WEIGHT of COPRA (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original %*	*% Free Fatty Acids (as lauric)*	*% Moisture*	*ANHYDROUS WEIGHT of COPRA (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original (Gms.)*	*TOTAL LOSS OF ANHYDROUS COPRA over original %*	*% Free Fatty Acids (as lauric)*
STAGE — 6										
START	9.0	2,608	—	—	—	9.0	2,495	—	—	—
2 ..	7.8	2,608	—	—	—	6.8	2,464	31	1.2	—
3 ..	7.0	2,607	1	trace	0.7	6.7	2,439	56	2.2	—
10 ..	8.0	2,530	78	3.0	1.4	5.5	2,432	63	2.5	1.1
15 ..	6.8	2,518	90	3.5	0.6	5.9	2,368	127	5.1	0.8
17 ..	6.0	2,510	98	3.8	0.9	5.5	2,359	136	5.5	1.4
21 ..	5.2	2,496	112	4.3	1.2	5.2	2,328	167	6.7	1.9
STAGE — 7										
START	7.8	2,695	—	—	—	7.8	2,675	—	—	—
2 ..	7.2	2,682	13	0.5	—	7.2	2,673	2	0.1	—
3 ..	6.6	2,681	14	0.5	0.1	6.7	2,660	15	0.6	—
10 ..	9.0	2,587	108	4.0	1.2	5.7	2,644	31	1.2	1.0
15 ..	6.9	2,579	116	4.3	0.6	5.4	2,552	123	4.6	0.8
17 ..	6.2	2,573	122	4.5	0.6	4.8	2,480	195	7.3	1.4
21 ..	5.5	2,558	137	5.1	0.7	4.2	2,360	315	11.8	2.0
STAGE — 8										
START	7.1	2,553	—	—	—	7.1	2,564	—	—	—
2 ..	6.9	2,540	13	0.5	—	6.8	2,530	34	1.3	—
3 ..	6.7	2,532	21	0.8	0.1	6.6	2,526	38	1.5	—
10 ..	9.1	2,464	89	3.5	1.4	5.4	2,517	47	1.8	1.1
15 ..	6.4	2,461	92	3.6	0.5	5.5	2,442	122	4.8	1.1
17 ..	5.6	2,444	109	4.3	0.7	4.9	2,403	161	6.3	2.0
21 ..	4.8	2,436	117	4.6	0.9	4.2	2,363	201	7.8	2.9
STAGE — 9										
START	6.8	2,338	—	—	—	6.8	2,466	—	—	—
2 ..	6.9	2,327	11	0.5	—	6.6	2,455	11	0.4	—
3 ..	6.9	2,323	15	0.6	0.1	6.4	2,451	15	0.6	—
10 ..	7.8	2,272	66	2.8	0.5	5.7	2,431	35	1.4	1.1
15 ..	6.8	2,266	72	3.1	0.5	5.6	2,361	105	4.3	0.8
17 ..	6.4	2,254	84	3.6	0.7	5.4	2,296	170	7.4	1.1
21 ..	6.1	2,228	110	4.7	0.8	5.3	2,247	219	8.9	1.4
STAGE — 10										
START	6.1	2,365	—	—	—	6.1	2,504	—	—	—
2 ..	6.8	2,360	5	0.2	—	6.1	2,498	6	0.2	—
3 ..	7.5	2,342	23	1.0	trace	6.1	2,486	18	0.7	—
10 ..	9.6	2,268	97	4.1	1.0	5.6	2,483	21	0.8	0.6
15 ..	6.4	2,259	106	4.5	0.8	6.1	2,396	108	4.3	0.7
17 ..	5.8	2,239	126	5.3	0.6	5.4	2,378	126	5.0	1.3
21 ..	5.2	2,232	133	5.6	0.4	4.8	2,336	168	6.7	1.8

It has been stated already that this experiment should be considered to be somewhat preliminary in nature. It should also be mentioned that it has not been possible to cope with a complete examination of all the samples in the experiment (at each of the intervals they were drawn) owing to the prodigious volume of manipulative and other work involved in sampling and analysis. Discretion had therefore to be exercised in the experimental programme so that work was restricted to essentials from the point of view of the specific information sought. The more important results of the studies, obtained so far, are charted in Tables XVII to XIX.

Table XVII will show that for the storage trial in the Air-conditioned Room, samples from Stage X alone were used. The purpose of the trial is of course to make observations on the keeping qualities of the well dried superior grade copra when stored under fairly stable conditions of temperature and humidity. The results convincingly show that for a period of 22 weeks (5 months) the total loss of anhydrous copra did not exceed 0.58 per-cent of the original weight. Though there was no apparent change in the percentage oil content (during this period), it will be seen further (column 8) that the true loss of oil amounts to 0.38 per-cent of this total. Even after 22 weeks the free acidity is only 0.11 per-cent. Though no pronounced micro-organic action was evident, it would appear that slow acting enzymes already generated in the meat (which act more on the oil than the fibre) are principally responsible for these losses. The experiment is being continued since there is evidence after 24 weeks of a sharp increase in the loss of anhydrous copra which may still be accounted for mainly by the removal of oil.

The results of the storage trials in the Well and Poorly Ventilated Stores are available in tabulations XVIII and XIX. Though the data available are less complete than those for the Air-Conditioned-Room, yet the results exemplify certain vital facts. It will be seen that there are irregular fluctuations in the moisture contents of the different samples during storage. In general, the tendency is for the very wet samples (Stages I to 8) to dry out progressively and for the dry ones (Stages 9 to 10) to absorb moisture during storage. This observation lends support to what has been mentioned earlier regarding the controlling effect of changes in atmospheric humidity on the contained and re-absorbed moisture in stored copra. Owing to the fact that only two thermo-hygrographs were available it was possible to keep temperature and humidity records only in the Air-Conditioned-Room and the Well Ventilated Estate Store. The average readings obtained over a period of six months are shown in Table XX.

TABLE XX

Recorded Average Temperature and Humidity Values in Storage Experiment
(Based on records kept for six months)

1	2						3					
STATISTICAL FACTOR OF VARIABILITY	*AIR-CONDITIONED ROOM*						*WELL-VENTILATED STORE*					
	Temperature (°F)			*Relative Humidity (%)*			*Temperature (°F)*			*Relative Humidity (%)*		
	Max.	*Min.*	*Mean*	*Max.*	*Min.*	*Mean*	*Max.*	*Min.*	*Mean*	*Max.*	*Min.*	*Mean*
	77.0	70.8	74.2	63.6	57.1	59.8	84.8	75.2	79.5	91.2	57.8	77.1
Standard Deviation	1.4	1.5	1.4	2.9	1.8	2.0	2.6	1.8	1.6	9.0	12.1	11.1
Coefficient of Variation %	1.8	2.1	1.8	4.5	3.2	3.4	3.1	2.4	2.1	9.9	20.9	14.4

With coefficients of variation ranging between 9.9 per-cent and 20.9 per-cent respectively for the maximum and minimum figures recorded for humidity in the Estate Store, the high range of variability is made quite obvious. For the Air-Conditioned-Room the corresponding range is only 4.5 per-cent and 3.2 per-cent. It will be seen that the temperatures are not so variable.

Regarding the actual quantitative losses of anhydrous copra, without doubt there are certain interesting and significant features in the results obtained. These are clearly elucidated by figures in the simplified Tables XXI to XXIII, which have been computed from the complete data that have been presented earlier.

TABLE XXI

Free Fatty Acidities of Samples in Storage Trials (Period — 21 weeks)
(Calculated as % lauric acid)

1	2			3			4		
STAGE	*AIR-CONDITIONED ROOM*			*WELL VENTILATED STORE*			*POORLY VENTILATED STORE*		
	Max.	*Min.*	*Average*	*Max.*	*Min.*	*Average*	*Max.*	*Min.*	*Average*
1 ..	—	—	—	4.7	4.1	4.5	8.2	5.0	7.1
2 ..	—	—	—	8.7	4.4	6.6	11.9	6.5	8.6
3 ..	—	—	—	3.8	2.0	2.9	7.5	4.0	5.6
4 ..	—	—	—	1.7	0.6	1.3	2.1	1.2	1.8
5 ..	—	—	—	1.5	0.6	1.1	1.9	1.0	1.4
6 ..	—	—	—	1.4	0.6	1.0	1.9	0.8	1.3
7 ..	—	—	—	1.2	0.1	0.6	2.0	0.8	1.3
8 ..	—	—	—	1.4	0.1	0.7	2.9	1.1	1.8
9 ..	—	—	—	0.8	0.1	0.5	1.4	0.8	1.1
10 ..	0.12	0.06	0.08	1.0	trace	0.7	1.8	0.6	1.1
Overall Average	—	—	—	2.6	1.3	2.0	4.2	2.2	3.1
RANGE	—	—	—	0.8 to 8.7	trace to 4.4	0.5 to 6.6	1.4 to 11.9	0.6 to 6.5	1.1 to 8.6

TABLE XXII

Loss of Anhydrous Copra in Storage Trials (Period — 21 Weeks)

(Total loss at different stages expressed as percentages of the original weights taken)

1	2	3			4		
STAGE	*% Initial Moisture*	*WELL VENTILATED STORE*			*POORLY VENTILATED STORE*		
		Maximum	*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*
1 ..	43.8	23.0	2.4	14.2	26.1	3.7	14.2
2 ..	33.8	29.9	10.2	22.2	25.1	7.4	17.6
3 ..	22.4	29.5	5.8	20.8	22.2	5.9	15.4
4 ..	12.5	13.4	2.8	9.1	7.9	1.4	4.7
5 ..	11.3	8.3	1.1	5.2	8.6	0.9	4.5
6 ..	9.0	4.3	0.0	2.4	6.7	1.2	3.9
7 ..	7.8	5.1	0.5	3.2	11.8	0.1	4.3
8 ..	7.1	4.6	0.5	2.9	7.8	1.3	3.9
9 ..	6.8	4.7	0.5	2.5	8.9	0.4	3.8
10 ..	6.1	5.6	0.2	3.4	6.7	0.2	3.0
Overall Average	16.1	12.8	2.4	8.6	13.2	2.3	7.5
RANGE	6.1 to 43.8	4.3 to 29.9	0.0 to 10.2	2.4 to 22.2	6.7 to 26.1	0.1 to 7.4	3.0 to 17.6

STAGE — 10 Stored in AIR-CONDITIONED-ROOM (Period — 24 Weeks)

	Per-Cent
Initial Moisture	6.1
Maximum Loss	0.96
Minimum Loss	0.38
Average Loss	0.60

TABLE XXIII

Moisture changes in Storage Trials (Period—21 Weeks) (Percentages)

1	2	3			4		
STAGE	*% Initial Moisture*	*WELL VENTILATED STORE*			*POORLY VENTILATED STORE*		
		Maximum	*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*
1 ..	43.8	43.8	5.4	9.2	43.8 +	6.2	9.3
2 ..	33.8	33.8	5.3	9.1	33.8	6.6	9.0
3 ..	22.4	22.4	6.1	7.2	22.4	5.1	7.2
4 ..	12.5	12.5	5.8	5.7	12.5	5.0	5.0
5 ..	11.3	*12.2	5.4	5.8	11.3	4.9	4.9
6 ..	9.0	9.0	5.2	5.0	9.0	5.2	4.5
7 ..	7.8	* 9.0	5.5	4.9	7.8	4.2	4.2
8 ..	7.1	* 9.1	4.8	4.7	7.1	4.2	4.0
9 ..	6.8	* 7.8	6.1	4.8	6.8	5.3	4.2
10 ..	6.1	* 9.6	5.2	4.7	6.1	4.8	4.0
Overall Average	16.1	16.9	5.5	6.1	16.1	5.2	5.6
RANGE	6.1 to 43.8	7.8 to 43.8	4.8 to 6.1	4.7 to 9.2	6.1 to 43.8	4.2 to 6.6	4.0 to 9.3

*These moisture figures *higher* than the initial were recorded after 10 weeks of Storage.

+ The maximum moisture contents in the Poorly Ventilated Store *never* exceeded the initial moisture contents during the 21 weeks, at any stage.

STAGE—10 Stored in AIR-CONDITIONED-ROOM (PERIOD—24 Weeks)

		Per-Cent
Initial Moisture	..	6.1
Maximum Moisture	..	6.1
Minimum Moisture	..	3.1
Average Moisture	..	4.8

That the type of storage definitely influences the extent and degree of deterioration is clearly shown by the analytical figures for free Acidity in Table XXI. It will be seen that regardless of the exact time stage in the experiment, at which samples are examined, the copra from the Poorly Ventilated Store would yield (relatively) the most inferior oil, with an average acidity of 3.1 per-cent ranging between 1.1 and 8.6 per-cent. The appropriate figures for the Well-Ventilated Store will be found to be 2.0 per-cent within the range 0.5 to 6.6 per-cent. Though samples from Stage 10 alone were stored in the Air-Conditioned Room, the results clearly show that for a 22-week period the acidity averaged only 0.08 per-cent (range 0.06 to 0.12 per-cent), which is about ten times lower than the acidities for the corresponding samples in the other Stores. It will be easily recognized that the highest acidities have been recorded for stages 1 to 3, where the initial moisture contents of the meat were over 20 per-cent.

Regarding actual losses of anhydrous copra, Table XXII, it will again be evident that the biggest losses have been recorded for stages 1 to 3. It would appear that when the initial moisture contents are high, conditions of good ventilation and aeration accentuate the activity of organisms resulting in bigger losses of anhydrous copra. When the copra dries out however to below 10 per-cent moisture, the position appears to be reversed so that these losses are somewhat greater under conditions of poor ventilation. The experiment also clearly shows that the initial moisture content of the copra coupled with moisture fluctuations during storage, play a vital role in the determination of the extent of these degenerative losses. Accordingly, it will be seen that the results of the present experiment, as far as they relate to losses of anhydrous copra, have to some extent been complicated by the phenomenon of moisture re-absorption, particularly in the Well-Ventilated Store. That this is so will be clearly evident from the figures summarised in Table XXIII. It will be seen that between stages 5 and 10 (after a period of 10 weeks' storage) the moisture contents of the samples in the Well-Ventilated Store were actually higher than the initial moisture contents of the respective stages at the commencement of the experiment. In the poorly Ventilated Store however moisture absorption to this extent did not occur at any stage. This is perhaps understandable when we consider the fact that whilst the air is stagnant under conditions of poor ventilation, it is continually displaced and renewed in a properly ventilated store. In the latter case therefore, the resultant tendency would be for greater fluctuations in moisture, depending on diurnal variations in temperature and humidity of the external atmosphere, and thus the incoming air. The different factors considered above would probably afford a tentative explanation for the overall losses of anhydrous copra recorded in Table XXIV for the three different conditions of storage.

TABLE XXIV

Overall Average Losses of Anhydrous Copra (Per-Cent) in 21 Weeks

1	2		3		4	
STAGE	*AIR-CONDITIONED ROOM*		*WELL-VENTILATED STORE*		*POORLY-VENTILATED STORE*	
	Average Moisture (Per-Cent)	*Loss of Anhydrous Copra (%)*	*Average Moisture (Per-Cent)*	*Loss of Anhydrous Copra (%)*	*Average Moisture (Per-Cent)*	*Loss of Anhydrous Copra (%)*
1 to 3	—	—	33.3 (Initial)	19.1	33.3 (Initial)	15.7
6 „ 10	—	—	7.4 (Initial)	2.9	7.4 (Initial)	3.8
1 „ 10	—	—	6.1	8.6	5.6	7.5
10	4.8	0.60	4.7	3.4	4.0	3.0

For Stage 10, the loss of anhydrous copra in the Well-Ventilated Store (3.4 per-cent) should normally be expected to be lower than for the Poorly-Ventilated Store (3.0 per-cent). The actual figures obtained could probably be explained on the basis that no moisture re-absorption took place (for this Stage) in the Poorly-Ventilated Store, whereas in the Well-Ventilated Store the moisture rose from the initial value of 6.1 per-cent to 9.6 per-cent after 10 weeks of storage (Tables XIX and XXIII), thereby inducing a greater loss of anhydrous copra.

At this stage it will be appropriate to consider the question of spoilage losses resulting from the production of 'copra dust' during deterioration. The losses in the foregoing experiment, considered so far, do not include the 'dust' produced during storage of the various samples. What has been reported as 'loss of anhydrous copra' represents only that weight of copra which has actually disappeared in the form of gas and moisture of decomposition. Any 'dust' produced in the various samples was not dislodged from the cups but was carefully weighed at the different stages with the loops. The need for a separate assessment of the losses from the production of dust is thus made clear.

As a corollary to the main experiment a separate study was made with the object of obtaining a preliminary assessment of the production of 'dust'. In order to avoid unwieldiness, samples from pre-determined stages alone were used. The selected samples were stored in aluminium trays in the Well-Ventilated Store. Weight and analytical records were kept at intervals over a period of 21 weeks. As it will be superfluous to present the complete data, only the computed results from the study showing the losses of anhydrous copra and dust (calculated as percentages of the original dry weight) are presented in Table XXV.

TABLE XXV

Losses of Anhydrous Copra and 'Dust' (after storage for 21 weeks) in relation to the Size-form of the Dried-Meat

WELL-VENTILATED STORE													
1		2			3			4			5		
STAGE		*FULL CUPS*			*QUARTER CUPS*			**STRIPS*			*+SLICED PIECES*		
		% LOSS			*% LOSS*			*% LOSS*			*% LOSS*		
NO.	*% Initial Moisture*	*Anhydrous Copra*	*Dust*	*Total*	*Anhydrous Copra*	*Dust*	*Total*	*Anhydrous Copra*	*Dust*	*Total*	*Anhydrous Copra*	*Dust*	*Total*
2	33.8	9.0	8.9	17.9	12.3	10.2	22.5	19.1	19.8	38.9	20.1	18.7	38.8
4	12.5	5.5	3.5	9.0	6.6	4.4	11.0	8.1	5.7	13.8	8.2	5.6	13.8
6	9.0	4.2	3.6	7.8	8.5	6.9	15.4	5.2	1.5	6.7	11.0	4.3	15.3
8	7.1	7.1	5.1	12.2	2.6	2.9	5.5	5.1	2.1	7.2	8.4	3.4	11.8
10	6.1	5.7	3.2	8.9	9.8	5.3	15.1	10.5	4.1	14.6	8.6	3.9	12.5
Overall Average	13.7	6.3	4.9	11.2	8.0	5.9	13.9	9.6	6.6	16.2	11.3	7.2	18.5
Averages as % of Total loss		56.3	43.7	100.0	57.6	42.4	100.0	59.3	40.7	100.0	61.1	38.9	100.0
Overall Loss of DUST as % of Loss of ANHYDROUS COPRA		77.8%			73.8%			68.8%			63.7%		71.0%

* Longitudinal
\+ As used for copra analysis.

Though the results obtained may appear inconclusive owing to the irregular variations of some of the individual figures, the overall averages show clearly that the losses of both anhydrous copra and 'dust' progressively increase with the reduction in the size-form of the dried copra. This would mean that from the point of view of losses through deterioration copra is best processed in the form of half-nuts (i.e. cups). In very general terms, the results show that the dust produced on storage is of the order of 70 per-cent of the loss of anhydrous copra. It should however be pointed out, that since only five selected stages were used for this study, the results are not strictly comparable with the results of the main experiment where ten stages were employed. It will doubtless be interesting and informative to repeat this study in the form of a proper experiment.

The question of actual losses and quality of the oil in these experiments has not been considered owing to the fact that it would not have been possible to cope with the prodigious volume of analytical work that would have been necessitated if samples were drawn for oil analysis at every stage of the experiment.

PROPOSALS FOR FUTURE WORK

That inferior copra resulting from careless production can seriously deteriorate with consequent economic losses to the producer and the industry has no doubt been recognized in producing countries. The literature survey already made gives clear evidence of this, since a fair amount of work has already been done to estimate the nature and extent of these losses. Though it is an undisputed fact, that in the preparation, storage, transport and shipment of a commodity like copra losses through deterioration are to some extent unavoidable, yet the importance of ascertaining permissible limits within which they should be maintained cannot be gainsaid. Mention has already been made that owing to the interplay of many factors, any conclusions drawn from experimental work carried out in one country are not necessarily comparable with those in another. If the most reliable information is to be had the best procedure would be for the different countries concerned to carry out experiments under prevailing conditions and practices peculiar to them. In the likely event of FAO organizing these investigations, it is considered that some suggestions for any possible lines of future work that may be undertaken on this subject, will be helpful.

Since fairly intensive work has already been done on the mycological and entomological factors responsible for these losses, this aspect would not require much attention. From the point of view of the industry invaluable information could be obtained if a proper experiment on a sound statistical foundation is conducted in each of the major coconut producing countries of the world. When this is done, any conclusions drawn can be established with validity on a proper scientific basis. It is further suggested that the experiment should be carried out on fairly big representative samples (at least 100 lbs. each) and conducted under conditions simulating those obtaining in commercial practice.

Proposed Experiment

The object of the proposed experiment would be to determine the total quantitative losses of anhydrous material and 'dust', resulting from the deterioration of copra in different stages of dehydration, when stored in the form of cups and fragmented kernels, under different conditions obtaining in commercial practice, for a period of six months.

DESIGN — Two replicates of a $3 \times 2 \times 4$ factorial experiment as shown below, necessitating 24 distinct treatment combinations (factors) and involving 48 samples in all.

TREATMENTS — (1) *Storage*

Small-holders store (a_1)

Bulk Store of Big Producer (a_2)

Shippers Store or Export Warehouse (a_3)

(2) *Size-form of Copra*

Half cups (b_1)

Fragmented kernels (b_2)

(3) *Dehydration*

Initial moisture 25% (c_1)

Initial moisture 15% (c_2)

Initial moisture 10% (c_3)

Initial moisture 6% (c_4)

EXPERIMENTAL DETAILS — It will be seen in the experiment that *four* stages of dehydration have been taken in conjunction with two different size-forms and *three* conditions of storage on the factorial system. For the first replicate the *eight* possible combinations of b and c will be stored on a pattern of random distribution under the *three* different conditions a_1, a_2, and a_3 making 24 samples (plots) in all. A similar random arrangement of 24 samples will be involved in the second replicate giving a total of 48 plots in all. The plan could be regarded as a randomised block layout made up of *six* blocks with eight plots in each, and is illustrated in Table XXVI.

TABLE XXVI

Plan of 3 × 2 × 4 Factorial Experiment

	SMALL-HOLDER'S STORE (a_1)		*BULK STORE OF BIG PRODUCER* (a_2)		*EXPORT WAREHOUSE* (a_3)	
REPLICATE - 1	b_1c_2	b_1c_4	b_2c_3	b_1c_2	b_2c_4	b_2c_3
	b_2c_1	b_1c_3	b_1c_3	b_2c_4	b_1c_1	b_2c_2
	b_2c_2	b_2c_4	b_1c_4	b_1c_1	b_1c_4	b_1c_2
	b_1c_1	b_2c_3	b_2c_1	b_2c_2	b_1c_3	b_2c_1
REPLICATE - 2	b_2c_2	b_1c_4	b_2c_1	b_1c_4	b_1c_2	b_2c_2
	b_2c_3	b_1c_2	b_1c_2	b_1c_3	b_2c_1	b_1c_3
	b_1c_1	b_2c_4	b_2c_2	b_1c_1	b_1c_4	b_2c_3
	b_1c_3	b_2c_1	b_2c_4	b_2c_3	b_2c_4	b_1c_1

It is felt that for each of the samples in the experiment 100 pounds of copra should be taken. These should be weighed at fortnightly intervals along with any dust produced. A second weighing should be done of the dust *alone*, which should again be bulked with the respective samples.

For the purpose of drawing samples for analysis separate lots of copra (each weighing about 200 pounds) representative of b_1c_1, b_1c_2, b_1c_3, b_1c_4, b_2c_1, b_2c_2, b_2c_3, and b_2c_4 should be kept in each of stores a_1, a_2 and a_3. Each time the 48 samples are weighed, corresponding samples should be drawn for quadruplicate moisture analyses. Since the analysis for oil content is likely to be unwieldy, these could be done probably at monthly intervals, using 40 — 60°C Petroleum ether as solvent. The free acidities could also be estimated once a month on the extracted oils.

The data accumulated from the experiment could then be analysed by the ordinary 'analysis of variance' procedure whereby the total variance can be carefully apportioned among the different factors responsible for the gross loss of anhydrous copra and dust. In other words, the losses due to deterioration with respect to each of the 48 plots will be statistically analysed (by the method of analysis of variance) so that it would be possible to determine the effect of each of the treatments and its interactions on the deterioration losses or to what extent they are controlled by these factors. The schedule in Table XXVII gives the form in which the statistical analysis of variance should be worked out.

TABLE XXVII

Analysis of Variance

SOURCE	*Degrees of Freedom (D.F.)*	*SS*	*MS*	*F (Significance)*
Replicates ..	1			
a ..	2			
b ..	1			
c ..	3			
a × b ..	2			
a × c ..	6			
b × c ..	3			
a × b × c ..	6			
Error ..	23			
Total ..	47			

SS = Sums of Squares   MS = Mean Square (*SS*) (*D.F.*)   F = Variance Ratio.

It would also be useful to get a recognized surveyor to grade the copra at pre-determined intervals, so that on the basis of his ratings the depreciation of the product in monetary value could also be assessed.

Records made from visual observations on the incidence of particular moulds and insects could also be kept for useful comparisons.

It would appear that some attempts have been made in the past to estimate the losses of copra through deterioration on shipboard during ocean transport. No records however are available to show that these are based on actual experiments. From the point of view of the industry, it would no doubt be useful if some data could be obtained on actual trial shipments of weighed bulk copra transported in the hold of the ship or on weighed samples shipped in jute bags. If such experiments are initiated, commercial sampling methods would of course have to be employed for drawing analytical samples both at the export centre and the place of destination of the trial consignments.

General Discussion

Though complete standardization would be difficult to establish in practice, it would doubtless be to the mutual benefit of all coconut producing countries, if regardless of the source of production, copra could be marketed on a common basis, so that each grade would be, as far as possible of the same relative quality. At present, each country has its own sorting and grading systems for the purpose of rating commercial copra, with the result that its quality could vary widely with its geographic origin. Further, a large number of classes have been necessitated in order to meet the requirements of the different factors — moisture content, oil content, free acidity and physical characteristics. This tendency has merely resulted in the progressive increase in the number of world grades that have now come to be recognized in international trade.

With the principal objective of exercising control over copra quality various countries have from time to time made attempts to introduce compulsory grading methods by legislative enactments. It has been their experience however, that such restrictive regulations have proved to be ineffective in practice. Where methods of compulsion have failed to produce the desired results, it is quite obvious that other ways and suitable inducements would be *sine qua nons* if national standards of production are to be advanced. In commercial transactions small lots of copra of exceptional quality are not valued at all at their true worth. Further, there are no incentives for the careful producer to voluntarily turn out copra of a quality higher than the average local standard required for purposes of export. Such being the situation at the present time in most producing and exporting countries, it is not surprising that well over half the world's copra, is sub-standard in quality and is handled commercially in an under-dried condition.

The present investigations coupled with research done in other countries have convincingly revealed the incontrovertible fact that half-cured and under-dried copra is a very unstable and unsatisfactory product. It is indeed very susceptible to processes of biological deterioration which bring in their train concomitant losses to the producer and the industry. It has been shown that these losses could assume very severe proportions under extreme conditions. The unfortunate fact is that the product that is unsatisfactory (both in quality and dryness) has been found to offer peculiar opportunities to dealers for malpractices and profit making, that are not realizable with the high quality reliable copra. This is a trend that has to be reversed by sustained propaganda, and the creation of adequate incentives for the production of the superior article. The results of the present investigations bear eloquent testimony to the fact that a serious economic problem is interwoven with the situation. It should be sufficiently appreciated, that when producers or dealers trade in the low grade, under-dried product, they are in effect not obtaining the maximum possible return from the crop. Perhaps it might be stated that they are even helpless in the face of existing trading conditions.

In the national interest, the producer who is not conscious of the aforementioned facts should firstly be educated and brought to a realization of the existent problems and their ramifications. It is with his co-operation alone that the wasteful losses to himself and the industry, resulting from an interplay of the medley of factors involved in processing, storage and transport could be averted or kept down to a minimum.

On the basis of the information available it should now be appropriate to proceed with an elucidation of the salient features of the losses that are involved in copra deterioration, as far as they affect the producer and the industry.

Depending on the period elapsing between manufacture and milling, that certain minimum losses must and will take place (even with the best quality copra stored under ideal conditions) cannot be questioned. These losses affect firstly the mass (or actual anhydrous weight) and secondly the quality of the oil or fat that can be recovered from the copra. The former may include a certain percentage of 'copra dust' which should also be reckoned as a 'spoilage loss' in spite of the fact that it contains a certain amount of highly acid oil.

The experimental data have shown that when the best quality estate copra (moisture 6.1 per-cent) is stored under ideal conditions in an Air-Conditioned Room where temperature and humidity fluctuations are very small, the total loss of anhydrous copra even after 5 months storage is under one per-cent. The contained oil had an acidity of only 0.12 per-cent. There was no production of dust and mould action was observed to be negligible. Such conditions of storage would of course not be practicable under commercial conditions.

The results obtained were interesting when samples drawn from the same high quality copra were stored under conditions of good and poor ventilation. Whilst in both cases the losses in anhydrous weight were of the same order (3.0 per-cent) the quality of oil from the former was somewhat better (acidity 0.7 per-cent) than that from the ill-ventilated store (1.1 per-cent). About 2.5 per-cent of dust was produced in each case. In spite of certain complications resulting from the phenomenon of moisture re-absorption the overall figures have given a clear indication that the actual conditions of storage play a vital and decisive role in the determination of the extent and degree of these degenerative losses.

When the above figures are compared with overall rough approximations of the figures obtained for raw and under-dried copra (Table XXVIII), the differences will indeed be found to be staggering.

TABLE XXVIII

Rough Approximations of % Overall Losses Calculated on Original Dry Weights

(Period — 5 months' Storage)

1	2	3	4	5			
				% LOSS			
CLASS	*DESCRIPTION OF COPRA*	*% Moisture*	*% Free Acidity*	*Anhydrous Copra*	*Dust*	*Total*	*Wasteful Loss (avoidable)*
	RAW						
A	(Grossly Under-Dried)	33	5.9	18	12	30	25
B	Under-Dried ..	12	1.5	9	6	15	10
C	Well-Dried ..	6	0.8	3	2	5	NIL

In the present experiment, the fundamental difference between the three classes (A), (B) and (C) is that (C) was carefully handled and properly dried whereas (A) and (B) were under-dried to different degrees. In other words, if (A) and (B) were also treated the same way and dehydrated to the same moisture content as (C) then the total losses would have also averaged about 5 per-cent, the same as (C). If we assume therefore that 5 per-cent is an unavoidable loss under typical conditions of manufacture and storage for 5 months then what could be described as 'wasteful loss' for the 'raw' copra would be 25 per-cent and for the 'under-dried' copra 10 per-cent.

Regarding the oil from the three classes, they could definitely be categorised into three distinct commercial grades (with appropriate price differentials), on the basis of their acidities alone.

To complete the picture, we could take export statistics into consideration, and proceed to work out on a monetary basis the actual losses in rupees that would be incurred by Ceylon's coconut industry during a period of one year. Before doing so, it should be mentioned that the 'unavoidable losses' which have been worked out at 5 per-cent, should be regarded as a reasonable estimate. In other words, it cannot be considered low, particularly in view of the fact that it relates to a period of 5 months. It is very dubious whether commercial copra would ever be kept in storage for such a long period after manufacture.

The average volume and value of copra and coconut oil exported from Ceylon during the five-year period 1955-1959, is as follows:—

	VOLUME (*tons*)	*VALUE* (*rupees*)
COPRA	46,231	44,126,336
COCONUT OIL	70,003	91,918,294

If the assumption is made that these statistics relate to well-dried, good quality copra, then using the experimental values for percentage 'wasteful losses' for (A) raw and (B) under-dried copra, we could readily calculate in rupees the financial losses to the industry, if the assumption is made that the product is exported in the form of (A) or (B). In other words, for the estimation of the respective losses, we have to assume that all the copra exported suffered 'avoidable' or 'wasteful' deterioration losses in weight to the extent of 25 per-cent, in the case of Raw Copra (A), and 10 per-cent, for the under-dried copra (B). The calculated financial losses for the three classes of copra would be as shown in Table XXIX below.

TABLE XXIX

Financial losses to the Industry on Exported Copra

1	2	3	4
CLASS	*DESCRIPTION OF COPRA*	*VALUE* (*Rupees*)	*LOSS TO INDUSTRY* (*Rupees*)
A	Raw ..	33,094,752	11,031,584
B	Under-dried ..	39,713,702	4,412,634
C	Well-dried ..	44,126,336	NIL

There is one point that needs emphasis. The computation for losses have been made purely on a weight basis. In actuality the losses would be higher if we take the quality factor also into account. In other words, weight for weight, the value of (B) would be lower than (C) and that of (A) would be lower than (B).

Finally, it should be mentioned that the figures computed for the financial losses would be further peaked up, if we take into account the losses resulting from deterioration on shipboard during ocean transport. The estimate of this loss has been stated earlier to range between 3 and 6 per-cent. There is also the question of losses from deterioration of the copra that is used in one way or another for domestic consumption. When all these are considered, it will be appreciated that the actual losses to the industry would truly assume fantastic proportions.

We could next consider the question of financial losses to the Industry, resulting from the production of inferior oil. On the basis of prices ruling at the present time, the calculated financial losses for the oil from the three classes of copra would be as shown in Table XXX. Similar assumptions to those made for computing the losses on copra have of course been found essential for these calculations as well.

TABLE XXX

Financial losses to the Industry on Exported Oil

1	2	3	4	5	6
CLASS	*SOURCE OF OIL*	*FREE ACIDITY %*	*PRICE per ton (rupees)*	*VALUE (rupees)*	*LOSS TO INDUSTRY (rupees)*
A	Raw Copra ..	5.9	950	66,502,850	25,415,544
B	Under-dried Copra ..	1.5	1,175	82,253,525	9,664,869
C	Well-dried Copra ..	0.8	1,313	91,918,394	—

The following figures represent the sum total of the annual financial losses to the industry that would result from the production of under-dried copra:—

Class	*Description*	*% Moisture*	*Financial Losses on Copra Rs. (millions)*	*Financial Losses on Oil Rs. (millions)*	*Total Rs. (millions)*
A	Raw Copra	33	11.0	25.4	36.4
B	Under-dried Copra	12	4.4	9.7	14.1

In summing up, if it is assumed that all the copra and oil annually exported from Ceylon have suffered deterioration losses to the extent of those represented by Classes (A) and (B), then the total annual financial losses to the industry (as the products leave the shores of the country) would be of the order of 36 million rupees for (A) and 14 million rupees for (B). If other factors are taken into consideration, then the true losses may be expected to mount up still higher.

Prevention of losses from Deterioration

From what has been discussed so far it should be evident that the deterioration of copra could result from a variety of factors. Assuming that the nuts have been carefully harvested, so that under-ripe and over-ripe drupes have been excluded, and that the pre-treatment has been satisfactory, the first 4-8 hours after splitting may be regarded as a very critical period. It is essential to reduce to a minimum the period of delay between splitting the nuts and applying heat. Even in the most perfect system of manufacture 8 hours (inclusive of the time taken to split) may be regarded as the maximum period of delay which is really permissible. The practice of overnight splitting of nuts is definitely one to be discouraged because there is every likelihood of advanced bacterial activity taking place rendering the copra liable to deterioration. The Ceylon method of sundrying for 5 hours prior to kiln drying is doubtless one of the best ways of preventing early contamination with bacteria. It should however be borne in mind that it is of primary importance to drain off thoroughly any coconut water from the cupped halves, else the sugars present would provide a ready target for bacterial attack. In a nutshell it all means that without the effective inhibition of bacterial infection any efforts for the preparation of superfine white copra without blemish or wrinkle would be just futile, because bacterial invasion implies discolouration and attack by penetrating moulds followed by insect infestation.

Regarding precautions at the drying stage, the first thing to remember is that heat should be applied before bacterial attack has had time to develop. It is not adequate merely to place the half nuts on the drying trellis of the kiln without delay. The kiln should be already warmed up and it should be so designed that the copra is not exposed to pockets or draughts of cold air. It is also important that the kiln should not be overloaded so that cold and humid conditions can prevail on the top surface of the bed of copra. Overloading not only prevents free air movement through the stacked copra but also causes the moisture laden air to produce a chilling effect. Unless appropriate precautions are taken conditions favourable for bacterial activity may predominate even inside the kiln. It is imperative therefore that faulty kilns and those of poor design should not be employed.

If sufficient care is not exercised, even properly dried good copra could deteriorate due to bad after-treatment. Careful handling, transport and storage are absolutely vital if copra is to reach its destination in good condition. It is important that copra should be kept in well ventilated dry stores and should never be allowed to get wet, else it will become liable to severe deterioration by moulds and insects. Since wet and poor quality copra are always foci of deterioration, they should never be stored alongside or blended with good copra.

In cases where mould cum insect infestation has already commenced the only practicable remedy for controlling further deterioration appears to be the use of fumigants, though it involves the use of undesirable poisonous vapours. Once the oil cells are ruptured and the oil comes into contact with the enzymes, the copra is bound to degenerate quickly regardless of its moisture content. The enzymes may be said to start off a sort of chain reaction which does egregious damage to the copra. It has been observed that the use of enzyme inactivators of inhibitors has ensured a fair measure of success, in preventing or arresting deterioration. In this connection gaseous sulphur-dioxide has been reported to give satisfactory results. It combines fungicidal and insecticidal properties with its potentiality for inactivating enzymes. Though some work has been done on problems of sterilizing, bleaching and fumigating deteriorated copra, further research in this field is considered worthwhile.

Conclusion

The production of copra constitutes one of the leading industries of many tropical countries. The principal use of commercial copra is of course 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 low free fatty acid content, the importance of producing quality copra should be appreciated by copra producers, marketing authorities and exporters alike.

Based on experimentally obtained values, an endeavour has been made to bring within the compass of this paper a certain amount of factual information bearing on the subject of copra deterioration and its economic implications to the industry. It is hoped that the significant features that have been brought into focus will enable a better understanding of the commercial and economic aspects of the problem of copra deterioration.

This study was initiated at the request of the Food and Agriculture Organization of the United Nations, with the principal objective of assisting the industry with a quantitative assessment of the economic losses that could result from the under dryage of copra.

The present investigations coupled with the survey made of available information, have revealed in no uncertain way that the economic losses to the coconut industry through the deterioration of copra could assume fantastic proportions under extreme circumstances. It has been pointed out that over 50 per-cent of the world's copra is handled in an under-dried condition and the consequent global losses could therefore be expected to be phenomenal.

It is fervently hoped that a multilateral endeavour at the international level will be made to arrest this trend, as there is very wide scope for the amelioration of the situation which is indeed unsatisfactory.

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