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# NUTRITION AND BIOCHEMISTRY OF THE COCONUT

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Coconuts are an indigenous product and a major article of commerce in many countries of the world which are suffering from protein deficiency. In recent years the importance of adequate protein in the daily diet, especially for the growing child of pre-school age, has been better documented and appreciated. That the world's ever-expanding, some would say exploding, population may fast outgrow our conventional protein food sources and create a major protein crisis or widen the protein gap is highlighted for us by the concern of governments and nutritionists. For example, in 1967, the United Nations General Assembly passed a resolution calling for concerted and coordinated action by the organization of the United Nations to combat protein malnutrition. The Food and Agriculture Organization of the United Nations has directed its Director-General "to promote all efforts to fill the protein gap by maximum use of both conventional sources and the exploitation of new sources of proteins."

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# NUTRITION AND BIOCHEMISTRY OF THE COCONUT [1]

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*Introduction.* Coconuts are an indigenous product and a major article of commerce in many countries of the world which are suffering from protein deficiency. In recent years the importance of adequate protein in the daily diet, especially for the growing child of pre-school age, has been better documented and appreciated. That the world's ever-expanding, some would say exploding, population may fast outgrow our conventional protein food sources and create a major protein crisis or widen the protein gap is highlighted for us by the concern of governments and nutritionists. For example, in 1967, the United Nations General Assembly passed a resolution calling for concerted and coordinated action by the organizations of the United Nations to combat protein malnutrtion. The Food and Agriculture Organization of the United Nations has directed its Director-General "to promote all efforts to fill the protein gap by maximum use of both conventional sources and the exploitation of new sources of proteins."

Coconuts are potential new source of proteins for human food use. A conservative estimate, probably on the low side, of world coconut production in the early 1960's gives 5.6 million tons a year, roughly equivalent to more than 200,000 tons of crude protein, only a minor proportion of which is presently being utilized for human food consumption. Our copra production alone n the Philippines would yield more than 80,000 tons of crude protein; again a conservative estimate.

The major proportion of coconuts is converted to coconut oil via copra. Commercial processes for extracting oil commonly use expellers at temperatures which denature proteins. Furthermore prevailing world practice in handling coconuts for the production and transportation of copra is not at all conducive to further utiliza-

[1] Read before the Chemical Society of the Philippines Annual Convention, 12 March 1971 held at the P. Garcia Memorial Hall.

tion of coconut meal for human food use. Here in the Philippines one needs only observe the drying of copra under the sun or in smoke-driers to verify this statement; it is further confirmed by seeing and smelling a shipment of copra to an oil mill, teeming with insects, moldy and perhaps with oil partly spoiled by rancidity and high fatty acid content.

*Review of previous work.* The coconut itself, compared to other oilseeds, contains little protein. Fresh coconut kernel would give a typical proximate analysis of 45% moisture, 4.1% protein, 37% fat, 8% carbohydrates, 3% crude fiber and 1% ash. (Compare with soybean which has 33.2% protein, 17.5% fat or cottonseed with 17.8% Proteins, 19.3 fat.) Inspite of this low protein content, coconuts become a potential protein source when one considers the worldwide production of coconuts — and this chiefly in areas suffering protein deficiency and lacking the other major oilseeds as important factors of their economy.

A fairly large amount of knowledge has been gathered on the nutritional value of coconut proteins: Protein Efficiency Ratio, Biological Value, Net Protein Utilization, Digestibilty. These studies have shown that coconut proteins compared suitably with a casein standard. Positive results in the growtth and well-being of undernourished children have been reported when these children were fed with protein-rich diets which included coconut proteins. A still unknown quantity in these feeding experiments is the amount of fiber an adult diet can take, which would limit use of coconut proteins. Even with this limitation, the 1968 Protein Advisory Group meeting could conclude that "there does seem to be a potential for an extended use of coconut in feeding young children, especially for use in village-prepared weaning foods." It should be noted, however, that these experiments were not conducted with commercial copra cake meal, but with especially processed coconut meal; protein preparations.

As regards the processing of coconut in order to obtain food-grade products, there have been to date many attempts. It does not seem necessary now to go into the details of these methods which attempt to recover oil and produce an edible protein material. A few words on some of them may be helpful.

We can conveniently divide these methods into three types: 1) Those which aim at producing high quality copra, 2) Those which process wet coconut meats, and 3) Those which process dried meats.

Two recent methods on producing high-grade copra may be mentioned: the Subrahmanyan process and drying with a heat-tent. The Subrahmanyan (or Philippines/FAO process) has been adequately described in a number of places. In essence, it calls for treating the coconut meat with an alkali or acid dip before sun-drying or just after *tapahan*-drying. The copra produced is high quality, free from odor, almost colorless, and with free fatty acid less than 1% (01%), even after storing for four months. Edible coconut meal has been prepared from this type of copra by the Food and Nutrition Research Center of the National Institute of Science and Technology; the meal has been successfully used in various food preparations.

The heat-tent method, developed by J.M. Bulder, FAO technical officer in Surinam, simply utilizes a small tent with a polyvinyl plastic roof. The coconuts, cut in halves, are dried atop wooden racks inside this tent. It is claimed that drying takes about three days during sunny days and about seven days during the rainy season, with just a little sunshine. Excellent quality copra is produced by this method. Mr. Bulder has given us samples of this copra which, though their outward appearance was moldy, gave excellent comparison with coconut meal prepared in the laboratory, as regards protein solubility.

Both processes which can easily be used by the small copra farmer suffer from the same difficulties. It takes time to have farmers change their traditional methods — and, in this case, they would also have to be convinced this would be financially profitable. The copra market does not seem to put such a lucrative premium on good quality copra inasmuch as the oil mills are presently structured for processing regular commercial copra, with poorer qualities than the copra produced by either method. As an official of a local oil refinery said to me, the Subrahmanyan process does not seem to have widespread use in the Philippines, and its good-quality product would not really be attractive to a refinery if the major bulk of their copra is still of the poorer type. They really would not save on processing costs since their whole plant operations are geared to the poorer lots. Mr. Bulder, whom I once

met, also expressed the same sentiments about his method. He is trying to convince copra farmers in Surinam to try the method — but he really could not promise them monetary returns for their efforts unless they could get a better price for their copra from the milling people: and the milling people could not give them a better price unless they could assure them of huge volumes of the 'good" copra.

A few words about processing wet meats and dried meats. Processing wet meats is an obvious method and gives good results for olives and fruits of palm trees. Applied to coconuts, however, the oil and water pressed out from coconut give an emulsion which has proved very difficult to handle and to break. As summarized in a report for the FAO meeting on coconut production, protection and processing in Djakarta in 1968, "The separation of the milk into oil and water forms indeed the crux of the whole problem of wet coconut processing. Of the various methods suggested or applied to solve this problem up to now none has been a sufficient success to be used regularly on a commercial scale. The reason for this are usually technical and/or economical difficulties." In other words, these wet processes just would not work commercially unless the oil yield is optimized, and the emulsion has prevented this.

The major processes referred to are the Robledano-Luzuriaga, the Kraus-Maffei, and the Chayen.

Today, at the Tropical Products Institute of the Ministry of Overseas Development, Great Britain, a wet process employing centrifugal separation of oil, water, and proteins at isoelectric point successfully gives a wet protein product, an isolate with 10% fat. At this stage, it is not known whether such an isolate would be useful. One possible use for it would be in manufacture of instant baby food, as for example, in the FAO developed process in Turkey. A high fat content could be an additional source of calories; on the other hand, problems such as shelf-life and packaging of a wet product would also have to be considered. TPI is happy with their oil and protein yields, and is presently studying the commercial possibility of their process.

Though processes working on dried meats avoid the problem of the oil-water emulsion, a new problem for them is the drying process and its additional cost inasmuch as coconut is 45% moisture.

Among such proceses are the Hiller, the Carver-Greenfield, and the Integrated Coconut Process at NIST here which uses a fluidized bed-dryer for the drying step. In these dried-meats processes, food grade products could be prepared if protein damage by heat (both in the drying and the oil-extraction steps) is avoided and proper hygienic conditions maintained.

To date, none of these processes has developed into commercial operation. As a Protein Advisory Group report in 1962 declared: "Pilot scale or commercial plants designed primarily to produce oil apparently have not yet managed to produce a satisfactory protein-containing foodstuff economically." The 1968 PAG meeting in Rome reiterates this: "Whereas a wide variety of methods have been developed and tested, none has as yet found commercial application for the production of coconut protein concentrates. There is still no clear view on what sort of end-products should be aimed at; therefore, the economic feasibility of the available processes cannot be assessed."

*Work at Texas A & M University.* The second part of this presentation will discuss work on coconuts done at Texas A&M University, College Station, Texas, USA. The overall project aims at developing an economically feasible process for the recovery of food grade products from coconuts. The research team is headed by Dr. Karl F. Mattil, head of Food Products Research of the University and Dr. Carl M. Cater, head of the University's Oilseed Products Research Center. I was part of the research team last year as assistant research chemist. I would like to gratefully acknowledge, in the name of the whole research staff doing coconut research at Texas A&M University, the support for the project by the United States Agency for International Development.

The work at Texas A&M Universitty may be considered in different stages: a first stage of "basic research" into the properties of coconut proteins; a second stage systematically studying the basic operations involved in different processes in order to evaluate their technical and economic feasibility, and a final stage involving a pilot plant, hopefully here in the Philippines. In the evaluation of each process, certain criteria have been established: the value of oil recovered, cost of the process, utilizability of the primary non-oil products, and disposability of by-products. Each of these criteria seems reasonable: any process developed to recover food-grade pro-

ducts from coconuts must maintain a comparable yield of coconut oil, the major economic product from coconuts: the process cost should be such that the commercial sector can make a commensurate profit for the extra processing involved: though food-grade products are obtained, their areas of utilizability must be demonstrated, furthermore, uses of non-protein products must also be shown, in order to interest commercial development; and finally, disposability of by-products increasingly takes on added importance on account of our growing concern for our environment.

I would now like to briefly outline some results obtained at Texas A&M University.

*Basic Research.* A certain amount of basic research on coconut was necessitated by the approach employed by the group. A member of the University's biochemistry department has been working on the ultrastructure of coconut meats by electron microscopy. These studies are aimed as a help towards the most effective cellular disruption which will give maximum recovery of fat and protein with minimum damage to each.

Other base information have been obtained using the classical laboratory approach. To insure that the work was being conducted on good quality coconut protein, care was taken to prepare coconut meal by laboratory processes not expected to denature proteins. Precedent for some of the basic research work was obtained from analogous work on soybean, cottonseed and sunflower seed. The shredded coconut meats were dehydrated in a freeze-drier, then solvent extracted with hexane. Meal so obtained, after further comminution had protein content 22.2%, 9.9% moisture upon equilibration, 1.1% oil. 5.1% ash, and 7.5% crude fiber.

Studies were made on protein solubility of coconut meal in aqueous and salt solutions over a range of pH's. In aqueous media, with only acid or base added to adjust the pH, a point of minimum solubility of about 10% was obtained at about pH 4. Solubility rises sharply towards pH 2 to about 80% and more slowly towards pH 11 (about 95%). As the curve rises towards the basic end, a hump is repeatedly observed at pH 8.0-8.5, suggesting two protein fractions at alkaline pH, one soluble at pH 8.0-8.5, the other at pH 10.5-11.

The solubility characteristics change dramatically in salt solutions, using varying salt concentrations from 0.25-1 molar and the salt used (sodium chloride, calcium chloride, sodium sulfite, dibasic sodium phosphate). There is usually a low solubility (about 20%) at pH 2 which rises sharply to a maximum of about 90-95% from pH 5. High solubility is maintained at alkaline pH, with a decline past pH 10. Classical Osborne classification studies on the meal have confirmed these solubility curves.

Other parameters of extraction studied were solvent; meal, ratio, length of time of extraction, temperature of extraction, and effect of added salts.

The next step was the actual isolation of coconut proteins at varying pH and salt conditions, in attempts to find a maximum recovery. Isolates were prepared at acid pH (pH2), close to neutral (pH 8) and alkaline pH (pH10.5).

Properties of these different isolates were studied: solubility over the pH range, amino acid analyses, 'functional properties" such as emulsification capacity, viscosity, coagulation properties, compatibility with wheat flour in leavened doughs, water holding capacity. Knowledge of these properties is important to a systematic knowledge of possible uses of coconut proteins, in case an economically feasible process for obtaining them could be developed; perhaps it would be better to say that such knowledge would be very important in really determining the economic feasibility of any process.

The second phase of the project, presently being investigated, is the study of various unit operations involved in processes, both dry and wet, for obtaining food grade coconut products. Among operations are drying of meats, oil recovery by uses of presses and solvent extraction, various mechanical comminution processes, and aspects of the wet process.

A couple of drying processes are being evaluated. With the cooperation of Franklin Baker Company of the Philippines, the possibility of starting a dry process with commercial desiccated coconut is being investigated. Studies on their commercial product which have been subjected to a proprietary pre-treatment for quality control, primarily salmonella control, showed that protein solubility was appreciably lessened, to about half of that of laboratory-pre-

pared meal. Franklin Baker has prepared desiccated coconut samples without the pre-treatment and preliminary studies have shown no protein denaturation as measured by solubility.

Furthermore, in cooperation with the V.D. Anderson Company, holder of the US license for the Carver-Greenfield process, results of a Carver-Greenfield plant in Ohio are also being evaluated. However, results to date have shown that, unless temperatures lower than their present 180 F can be utilized, substantial protein denaturation results.

The particle comminution step is very important in any dry process, prior to oil and protein extraction. The particular mechanical process used (press or mill or combination of both) strongly influences the ease of oil and protein extraction. At the same time, temperatures attained cannot be too elevated because of protein denaturation.

Solvent extraction of coconut, without prior mechanical removal of some oil, seems to present unique technological problems on account of the large oil content of the coconut. Using repetitive immersions of milled coconut in hexane, 10-15 immersions were required to bring the residual oil to about 4.5% In comparison, residual oil is reduced to less than 1% or less in soybeans or cottonseed with 4-5 immersions under the same conditions. Thus some form of mechanical process for removing most of the oil must be utilized, without, however, using temperatures which denature proteins and without producing a meal cake which will make efficient solvent percolation difficult.

Attempts are also being made to prepare a milk-like beverage, following the US Food and Drug Administration standards of identity for such a product and trying to obtain a viscosity close to milk. To date the group has not been able to raise the calcium and phosphorus levels to those recommended by the standards without obtaining a precipitate. Using an emulsifier, it has been possible, however, to obtain a milk-like emulsion with 3.25% oil, 4% protein and 5.3% sucrose. Its calcium and phosphorus content was only a third of the recommended levels and its viscosity and oil-globular size were different from milk.

*Conclusion.* I hope that this review of work done in developing processes towards obtaining food grade products from coconuts has

shown some of the progress made. At the same time, we should not lose sight of the great technological challenge involved in developing an economically feasible process. The work has been done world-wide by a whole array of scientists: in the Philippines, Thailand, Ceylon and India, in Jamica and Great Britain, in Latin America and the United States.

A few criteria for a successful process seem fixed. Coconut products, primarily as copra and coconut oil, are of fundamental importance to the national economies of some of the coconut-producing countries, certainly here in the Philippines. Therefore, any process developed must keep that structure: the oil yield must be comparable to present levels for the new process to survive economically. Furthermore, it should be remembered that coconut proteins have competition in the field of unconventional vegetable protein sources from soybean, cottonseed and possibly became rapeseed and sunflower seed. One should also remember that a new process may have to revolutionize the prevailing world practices in handling of coconuts — a formidable task indeed.

Knowledge of the basic properties of coconut proteins can be a big aid in finding uses for these proteins which may help their economic feasibility. Therefore, the researchers should keep an open mind as to what products they expect from coconut proteins. As the PAG report said, "There is still no clear view of what sort of end-products should be aimed at."

Nevertheless, regardless of all these technical cultural and economic difficulties, we must never lose sight of the ultimate goal, that all this work may yield its greatest dividend of opening up a large yet untapped source of high quality proteins for our hungry world. This alone is justification enough: to feed our hungry world.