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Effects of processing on protein nutritive quality of coconut *Cocos nucifera* products

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Abstract. Pared, comminuted and blanched coconut meat was freeze-dried at 25 °C for 24 hours and pulverized. Whole coconut meal was solvent extracted with n-hexane to yield a defatted meal while full-fat coconut protein concentrate (FFC-PC) containing 27.60% protein was prepared by alkali extraction of undefatted meal followed by isoelectric precipitation. Defatted coconut meal had a significantly ($p \leq 0.05$) lower crude fat but higher protein content than whole coconut meal. Similarly, FFC-PC had a significantly ($p \leq 0.05$) higher protein but lower carbohydrate content than whole coconut meal and defatted coconut meal. Whole coconut meal, defatted coconut meal and FFC-PC had PERs of 1.98, 2.18 and 2.48 respectively, with NPRs of 2.86, 3.28 and 3.92, respectively. Protein digestibility values of 88.75%, 89.30% and 94.02% were obtained for whole coconut meal, defatted coconut meal and full-fat coconut protein concentrate, respectively. Growth response of animals showed that FPC-PC was superior to all other test diets.

Key words: Coconut meal, Defatted coconut meal, FFC-PC, PER, NPR

Introduction

Coconuts are among the most important oil-bearing fruits in world trade that are grown over the widest possible area and used in a wide variety of foods [1–2]. The emphasis in coconut processing, to this point, has been on oil extraction while protein extraction has received very little attention [3]. The advent of modern technology in processing of oil-bearing materials for extraction of oil has resulted in a variety of oil-free residues including oil-free coconut cake which contains moderate amounts (18–25%) of protein [4]. This residual cake is generally unfit for human consumption and, thus, used for animal feed, fertilizer or at times simply discarded [3, 4]. Considering the excellent quality protein which coconut cake can provide to dietary protein in human nutrition, the present uses appear wasteful. Coconut proteins contain a high percentage of lysine, cystine, histidine, arginine, methionine and other essential amino acids [1]. Special attention is now being devoted to concentration and isolation of proteins from oil seeds and legumes [5–8]. Such

concentrates and isolates offer greater opportunity for incorporation into and supplementation of a broad variety of foods and may particularly fit the needs of infants whose protein needs are critical [9]. Since various processing conditions affect protein quality, the ultimate protein nutritive value of coconut products would be determined by the nature and extent of processing and also by the efficiency with which the proteins are used in feeding trials with animals. Most of the publications on food uses of coconuts are centered around coconut oil, copra and meal as well as coconut milk and desiccated coconuts. Information on the extraction of coconut proteins as well as the protein nutritive quality of coconut meal and protein concentrate are scant. The present study was undertaken to determine the effects of processing on nutritive quality of proteins derived from coconuts.

Materials and methods

Sample preparation. Whole coconut meal, defatted coconut meal and full-fat coconut protein concentrate (FFC-PC) were processed by modification of the methods of Bera & Mukherjee [10] (Figure 1). The method involves freeze-drying and pulverizing of pared, comminuted and blanched coconut meat to obtain a meal. Whole coconut meal was solvent-extracted with n-hexane to remove free oil and dried at 30 °C for 24 hours in a Gallenkamp hotbox air recirculating oven (Size 1, England). In another experiment, 1 g of whole coconut meal was dispersed in 20 ml distilled water and extracted for 30 mins in a temperature-controlled waterbath (Raymond A. Lamb, No. E65-525, England). The pH of the dispersion was adjusted using 1 N NaOH solution and constant stirring. The dispersion was centrifuged at 1000 × g for 30 min. Proteins in the supernatant were then precipitated by adjusting the pH to 4.5 with 1 N HCl and further centrifugation at 1000 × g for 30 min. The solids were recovered, resuspended, neutralized and freeze-dried at 25 °C. Dried protein concentrate was ground in a Kenwood Food Processor (Model 967A, England), sieved through 20 mesh screen and sealed in polythene bags then stored in a desiccator.

Chemical analysis. Samples of ground whole coconut meal, defatted coconut meal and full-fat coconut protein concentrate (FFC-PC) were analyzed for their proximate contents. Analyses for moisture, protein (N × 6.25), crude fat, crude fiber and ash contents were carried out using to AOAC methods [11]. Total available carbohydrate was analyzed using the Clegg-Anthrone reagent method of Osborne & Voogt [12].

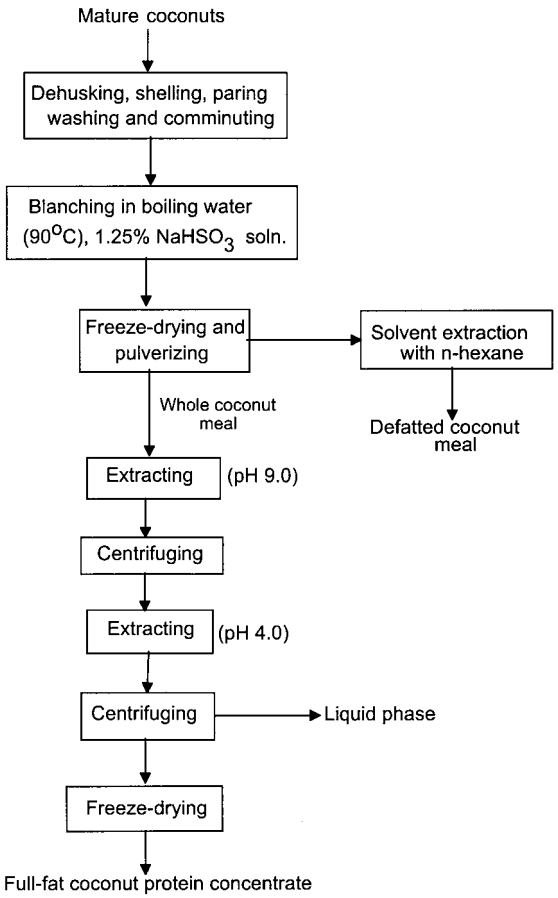

Figure 1. Flow chart illustrating the production sequence for whole coconut meal, defatted coconut meal and full-fat coconut protein concentrate.

Biological evaluation of protein quality. For biological evaluation, four isonitrogenous (by calculation) diets were prepared according to AOAC methods [11]. Based on Kjeldahl analysis of samples (N × 6.25) each test material was included in its corresponding diet at a 10% protein level; each served as the source of protein. The diets were adjusted, according to the proximate analysis of the test materials, so that all diets had the composition outlined in Table 1. Vitamin-free casein (BDH, Poole, England) was used as the reference protein and was added to the appropriate diet at a 10% level. A non-protein diet (corn starch) was also prepared having the same nutrient percentage with the exception of additional sucrose being substituted for the protein. Fifty, 21 days old weanling male albino Wistar rats weighing between 42–48g were obtained from the Department of Biological Sciences and used. The experi-

Table 1. Diets containing various protein sources derived from coconuts or casein

Ingredients[1]	Diets			
	WCM	DCM	FFC-PC	Casein
Whole coconut meal	49.90			
Defatted coconut meal		42.34		
Full-fat coconut protein concentrate			36.23	
Casein				10.32
Corn starch	30.0	34.0	40.0	55.0
Sucrose	16.0	18.0	18.0	20.0
Corn oil	2.10	3.66	3.66	7.68
Salt mixture[2]	1.0	1.0	1.0	5.0
Vitamin mixture[3]	1.0	1.0	1.0	1.0
Non nutritive fiber				1.0

[1] Named after their protein source. WCM = Whole coconut meal. DCM = Defatted coconut meal. FFC-PC = Full fat coconut protein concentrate.

[2,3] Prepared by F. Hoffman-La Roche & Co. Ag., Basel, Switzerland, based on formulation by Clarke et al. [13] for laboratory animals. Salt mixture composition (content 1 kg): Calcium 6.0 g; Chloride 5.0 g; Copper 10 mg; Iodine 0.2 mg; Magnesium 2.0 g; Manganese 75 mg; Phosphorus 5.0 g; Potassium 5.0 g; Zinc 18.0 mg.

Vitamin mixture[3] contained (International Units, I.U. or mg or μg/kg diet): Vitamin A 700 (I.U.); Vitamin D 300 (I.U.); Vitamin E 60 (I.U.); Vitamin K, 2.9 (mg); Thiamin HCl 4.0 (mg); Riboflavin 5.0 mg; Pyridoxine HCl 5.0 mg; Niacin 10 mg; Pantothenic acid 120 mg; Cobalamin (B_{12}) 5.0 μg.

mental arrangement was a completely randomized block design involving five treatments, consisting of the experimental diets: whole coconut meal, defatted coconut meal, full-fat coconut protein concentrate (FFC-PC) and the controls, casein and corn starch. The diets were fed to five groups of ten rats each, individually housed in galvanized steel cages in a room at a temperature of 30–32 °C. A 12 hr light dark cycle was used. After an acclimatization period of three days during which the rats were fed standard rat chow, test diets and water were fed *ad libitum* for 28 days. Fresh feed was provided daily and individual body weight, feed intake and feed wastes were recorded for a period of 28 days. The average 28 day weight gains and protein (N $\times$ 6.25) intakes per rat for each group were calculated. The protein efficiency ratio (PER) for each group was calculated and values adjusted to 2.5 for reference

casein. Net protein ratio (NPR) was determined by the method of Bender and Doell as described by Peller & Young [14]. The digestibility of the diets was determined by the method outlined by the same authors.

Statistical analysis

A completely randomized block design was used in this experiment. An F-test was used to determine significant differences at $p \leq 0.05$. When analysis of variance revealed a significant effect, means were separated using the Fisher's least significant difference (LSD) procedure described by Steel & Torrie [15].

Results and discussion

Figure 1 data show the production sequence for whole coconut meal, defatted coconut meal and full-fat coconut protein concentrate (FFC-PC). Blanching of sliced coconut meat in boiling $NaHSO_3$ solution for 5 min enhanced the oxidative and color stability of the pulverized coconut meal. Pulverizing of dehydrated coconut meat followed by the two-stage, centrifugation of extracts prepared at various pHs enhanced separation of the proteins from other constituents of the meal. According to Kwon et al. [3], this aqueous process for the extraction of oil seed proteins would be important in the recovery of high quality oil and food grade proteins from coconut. The aqueous extraction process (AEP) has been successfully applied to peanuts and to a lesser extent winged beans [16], lupine seeds and palm kernels [5, 7].

Data in Table 2 show the proximate composition of processed coconut products. Defatted coconut meal had a significantly ($p \leq 0.05$) lower content of crude fat but higher protein content than whole coconut meal. Differences in the values for moisture and ash contents of the three coconut products were non-significant ($p > 0.05$). With respect to treatment effects, defatting of whole coconut meal as well as its concentration to yield FFC-PC, resulted in the removal of oil and carbohydrates by the extraction solvents (hexane and alkaline solutions) used in preparation of defatted meal and FFC-PC, respectively. This resulted in significantly ($p \leq 0.05$) lower carbohydrate and crude fiber contents in the FFC-PC compared with the defatted coconut meal. These results are supported by those of Onwudike [17]. Studies have shown [17, 18] that coconut oil contains about 85% saturated fatty acids and 15% unsaturated fatty acids with lauric, myristic and palmitic acids as the most predominant fatty acids. Several epidemiological studies [19, 20] have shown that there is a moderately good correlation between the serum cholesterol level in individuals and the consumption of saturated fatty acids. These workers are, however,

Table 2. Proximate composition of processed coconut products*

Products	Moisture (%)	Crude fat (%)	Crude fiber (%)	Protein (N × 6.25)	Carbohydrates (%)	Ash (%)
Whole coconut meal	7.65[a]	8.52[ab]	9.08[a]	20.04[a]	49.56[b]	5.24[a]
Defatted coconut meal	7.48[a]	5.36[a]	11.04[ab]	23.62[b]	47.36[b]	5.12[a]
Full-fat coconut protein concentrate	6.96[a]	7.40[a]	8.20[a]	27.60[c]	43.80[a]	6.02[a]

* Based on dry weight of products.
[a,b,c] Means in the columns not followed by the same superscripts are significantly different ($p \leq 0.05$).

of the opinion that such data could be misleading because these correlations were purely mathematical in nature and did not prove a cause – and – effect relationship. In a seven country study, Keys [21] suggested a mathematical formula aimed at predicting changes in serum cholesterol level according to changes in the intake of saturated fatty acids and polyunsaturated fatty acids (PUFA). These workers showed that stearic acid (C18: 0) had no influence on blood cholesterol level and suggested that this saturated fatty acid could be omitted when using the formula. The same probably held for readily metabolized short-chain saturated fatty acids (C4: 0 to C10: 0) which are important constituents of butter and coconut oil. Keys' [21] formula might therefore be applied only to C12, C14 and C16 saturated fatty acids. It is difficult to understand why stearic acid, a long chain fatty acid, would have no effect on blood cholesterol when lauric, myristic and palmitic acids with shorter chain lengths would be active. It has been contended [22] that if the Keys' [21] formula was applicable, then 95% of the saturated fatty acids found in beef and pork, 50% of the saturated fatty acids in butter oil and 20% of the saturated fatty acids found in coconut oil might be without effect on blood cholesterol level. Medium chain triglycerides (MCT), (C8: 0 and C10: 0), fractionated from coconut oil, have been used in dietetics because they do not require pancreatic lipase like long chain triglycerides and, once absorbed, they go directly to the liver in the portal vein [23]. Patients with steatorrhoea are known to absorb MCT much better than other fats. Thus, MCT are a valuable source of energy for such patients [23].

It has been suggested [17] that the high degree of saturation of coconut oil accounts for its use for confections, baked goods and deep fat frying. Besides, in many milk deficient areas of the world, coconut oil mixed with nonfat milk solids have been used as replacements for whole milk for many purposes, including the feeding of infants [24, 25]. Such milk preparations are known to have better keeping qualities than cows' milk. These special qualities of coconut oil have been attributed to a high percentage of lauric, myristic, palmitic and oleic acids [17, 25]. In Nigeria, SMA, Mamex and Dumex are various brands of commercially available infant foods imported from Wyeth (Ireland) Ltd., Ireland and Dumex Ltd., respectively. These infant formulations, which have various levels of coconut oil/meal in combination with other ingredients [26] are widely accepted and have been used without adverse reports. Besides, desiccated coconut and whole coconut milk are among the various coconut foods from the Philippines in international trade [25]. These foods, as well as other coconut products, are often consumed with other products such as snacks or as part of a main meal. Thus, coconut products may not pose a problem of elevation of blood lipid level especially as they are consumed with other foods that serve as sources of polyunsaturated fatty acids (PUFA). Literature sources also indicate a much wider use of coconut oil/meal in human nutrition [18, 22] as well as in animals [27, 28] without adverse effects, especially as they are not consumed alone.

Data on the protein nutritive value of processed coconut products are shown in Table 3. The results show that whole coconut meal, defatted coconut meal and FFC-PC supported growth of the experimental animals. Differences in the values obtained for the weight gain of rats fed the various diets were significant ($p \leq 0.05$). The weight gain, protein intake and % protein digestibility of rats fed the FFC-PC diet were significantly ($p \leq 0.05$) higher compared with those fed either the whole coconut meal or defatted coconut meal diets. With the exception of weight gain, there was no significant ($p > 0.05$) difference between the growth responses of rats fed FFC-PC and casein diets. Differences in the values obtained for the PER (1.98, 2.18, 2.48) and NPR (2.86, 3.28 and 3.92) of the whole coconut meal, defatted meal and FFC-PC, respectively, were nonsignificant ($p \leq 0.05$). Similarly, studies [29] have shown that the PER of spray dried safflower protein isolate (SPI) and safflower meal were not significantly different and that the PER of SPI also compared favorably with the ANRC reference protein. Net protein ratio (NPR) is a measure of the total nitrogen retained in the weanling rat and is a direct measurement of utilization of dietary protein [30]. The FFC-PC diet resulted in higher nitrogen retention than either the whole coconut meal or defatted coconut meal diet. This was expected considering that this was the protein concentrate. The results (Table 3) show that the amount and quality of

Table 3. Protein nutritive value of processed coconut products

Diets	Weight gain (g)	Protein intake (g)	PER	C-PER	NPR	% Protein digestibility
Whole coconut meal	25.60[a]	12.92[a]	1.98[a]	2.64[a]	2.86[a]	88.75[a]
Defatted coconut meal	31.39[b]	14.40[a]	2.18[a]	2.55[a]	3.28[a]	89.30[a]
Full-fat coconut protein concentrate	44.40[b]	17.92[b]	2.48[a]	2.50[a]	3.92[a]	94.02[b]
Casein	37.80[c]	16.01[ab]	2.36[a]	2.50[a]	3.69[a]	92.40[ab]

PER = Protein Efficiency Ratio.
C-PER = Corrected or Adjusted PER for Casein = 2.50.
NPR = Net Protein Ratio.
[a,b,c] Means in the columns not followed by same superscripts are significantly different ($p \leq 0.05$).

food consumed by the experimental animals greatly influenced their response. This finding supports the results of Fashakin et al. [31]. The PER results of animals fed whole coconut meal were slightly lower than those reported by some workers [32] but supported by the results of Gonzalez [25]. Growth response of the animals showed that FFC-PC was superior to all other tested diets. The PER and NPR results of FFC-PC fed animals were also lower than the literature value. This was expected because the literature value [33] was based on fiber-free coconut extracts. It is known that the biological value of coconut proteins is compromised as the fiber content of the meal is increased. The observation of high feed digestibility with corresponding low PER seen in this study has been noted for fermented and unfermented African oil bean seed [34] and fluted pumpkin seeds [35] and heat processed isolated soybean protein [36]. Protein digestibility may sometimes provide a misleading indication of nutritional value [36]. Protein utilization as represented by PER and NPR in this study was affected not only by the level of limiting amino acids but also by the level of essential amino acids present in high amounts [36]. In proteins damaged as a result of processing, some of the amino acids may be absorbed in bound forms that may not be utilized by animals [36]. These observations may be applicable in the present findings with coconut.

Defatting of coconut meal significantly ($p \leq 0.05$) increased its protein and crude fiber contents because the crude fat and soluble carbohydrates were removed in the extracting solvents. The bioavailability of the protein was, however, compromized by this significantly ($p \leq 0.05$) higher fiber content of the defatted meal. Alkaline extraction of whole coconut meal followed by isoelectric precipitation of the proteins yielded a FFC-PC with a PER of 2.48, NPR of 3.92 and protein digestibility of 94.02%. This is a significant improvement from the traditional dry processing of coconut meat [37] which represents a significant waste of coconut proteins. Coconut is available in areas where protein malnutrition is also prevalent [37]. Before now, copra cake and meal byproducts from traditional processing have been used primarily for animal feed. Experimental work of the kind reported in this paper has established a potentially useful coconut product for use in food manufacturing industries. Coconut meat is an effective starting material for protein concentrate production. Coconut meal/protein concentrate could potentially be used to enrich cereal flours in the preparation of bread, biscuits and cakes. Studies on the functional properties of whole coconut meal, defatted coconut meal and FFC-PC would further illuminate their potential as functional ingredients in food systems.

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