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Some Nutritional and Anti-nutritional Characteristics of Para-rubber (*Hevea brasiliensis*) Seeds

V. Ravindran[a] & G. Ravindran[b]

[a] Department of Animal Science, [b] Department of Food Science and Technology, University of Peradeniya, Peradeniya, Sri Lanka

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ABSTRACT

*Para-rubber (*Hevea brasiliensis*) seeds were examined for their proximate analysis, detergent fibre, amino acid and mineral composition. The seeds were further analysed for the presence of anti-trypsin activity, cyanide, phytate and tannins.*

The average composition of the seed kernel was determined to be (dry matter basis) 21·5% crude protein, 50·2% crude fat, 6·5% crude fibre, 3·6% ash and 18·2% carbohydrates. The amino acid profile, when compared with the NAS/NRC reference protein pattern, revealed deficiencies of lysine, isoleucine and threonine. The seed kernels contained reasonable amounts of trace minerals, but were poor sources of Ca and P.

Fresh seed kernel samples contained toxic levels of HCN (164 mg/100 g dry weight), but most of the cyanide was eliminated by storage and cooking. The relatively high content of phytate P (37·5% of total P) may be expected to further aggravate the problem of low P and to cause severe Ca/P imbalance. No antitryptic activity or tannins could be detected in the samples studied. Because of the presence of an anti-fertility factor and collection and storage problems, it is concluded that rubber seeds show little promise as a human food in normal times.

INTRODUCTION

Inadequate availability and low intake of protein foods, coupled with a fast growing population, make protein malnutrition a serious threat to the

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future of most developing countries. The lower income groups (below the 'poverty line') are particularly vulnerable and finding practical ways to overcome this situation has become a major concern of nutritionists around the world.

Para-rubber (*Hevea brasiliensis*) trees are grown on over four million hectares of the world's surface for the production of natural rubber. The major rubber-producing countries are in South and South East Asia. In addition to the economically important latex, the tree also produces an estimated 800–1200 kg rubber seeds per hectare per annum (Stosic & Kaykay, 1981). However, the actual net yield is considerably lower than this due to practical problems of collection. A realistic collectable yield is probably around 150–200 kg per hectare. Accordingly, the annual world production of rubber seeds would amount to about 700,000 tonnes.

The potential commercial uses of rubber seeds have been known for almost a century (Anon, 1903). That properly processed seeds of the para-rubber and other *Hevea* species have been, and still are, consumed by the native Indians of the Amazon and people living around Indonesian rubber plantations, is amply attested to by the literature (Giok *et al.*, 1967; Wheeler, 1978). The seed kernels are either roasted, fermented or boiled before consumption. The usefulness of rubber seeds as an animal feedstuff has also been recently evaluated (Stosic & Kaykay, 1981). Despite this upsurge of interest, literature on the nutrient composition of rubber seeds is rather inadequate. Apart from hydrocyanic acid (Georgi *et al.*, 1932), the possible presence of other anti-nutritional factors has not yet been determined. The study reported herein was undertaken to investigate the nutritional and anti-nutritional characteristics of para-rubber seeds.

MATERIALS AND METHODS

Samples

The para-rubber tree starts bearing fruit at four years of age. Each fruit contains three to four large brown mottled seeds which dehisce explosively, scattering the seeds. The seed consists of a thin hard shell around a cream-coloured kernel.

Rubber seed production is seasonal in nature. In most areas of Sri Lanka, July to September is the fruiting season. The seeds used in the present study were collected in four batches during the fruiting seasons of 1983 and 1984. About 2 kg of each batch were weighed and decorticated manually to determine the shell:kernel ratio. The kernels in each batch were bulked and stored in polythene bags at −4°C. The kernels were removed as necessary and defatted by the use of methanol–chloroform (2:1 v/v). Defatted samples were dried and ground in a laboratory mill to pass through a 60-mesh sieve.

A batch of undecorticated seeds was stored at room temperature (22–28°C) to obtain preliminary information on the keeping quality of the seeds.

Chemical analysis

Full-fat kernels were used in the estimation of moisture, food energy and crude fat contents. All other analyses were done on defatted samples. The details of analytical methods used, except for silica, cutin, non-protein nitrogen, starch and trypsin inhibitor activity, have been described elsewhere (Ravindran & Ravindran, 1987).

Non-protein nitrogen was estimated by the method reported by Singh & Jambunathan (1981). Starch content was determined according to the procedure of Pucher *et al.* (1948) which involved extraction of starch with perchloric acid, separation of starch as the iodine complex, decomposition of the complex with alkali and measurement of starch by the phenol–sulphuric acid method (Dubois *et al.*, 1956). Silica and cutin fractions were determined by the method of Goering & Van Soest (1970).

The trypsin inhibitor was extracted with phosphate buffer (0·1 M, pH 7·6) and the trypsin inhibitor activity was determined by the method of Kakade *et al.* (1969).

All four batches of rubber seed kernels were subjected to proximate and detergent fibre analysis, while other analyses were made only on a representative sample. Rubber seed shells were also analysed for proximate and detergent fibre components to assess their potential uses.

RESULTS AND DISCUSSION

The seed weights in our samples varied from 3·1 g to 6·3 g with most seeds weighing closer to the average of 4·8 g. The variation in seed weight appears partly related to the differences in moisture content of kernels. The average moisture content of fresh rubber seed kernels was determined to be 28·9% (Table 1). Under normal storage conditions, the kernels lose moisture and shrink with time.

When decorticated, the shell (outer hull) represented 42–51% and the kernel (cotyledon) was 49–58% of the total seed weight. Well-formed kernels were found in over 90% of the seeds.

The full-fat seed kernels contained an average of 21·5% crude protein and 50·2% crude fat (Table 1). On a fat-free basis, the protein content

TABLE 1

Proximate Analysis and Fibre Composition of Full-fat Rubber Seed Kernels and Rubber Seed Shells in Per Cent Dry Weight (Mean ± Standard Error)[a]

	Full-fat rubber seed kernel	*Rubber seed shell*
Moisture (wet weight)	28·9 ± 0·5	4·4 ± 0·3
Food energy (kcal)	707 ± 16	378 ± 7
Crude protein (N × 6·25)	21·5 ± 0·6	2·6 ± 0·2
Crude fat	50·2 ± 0·4	1·0 ± 0·2
Crude fibre	6·5 ± 0·5	68·9 ± 0·9
Ash	3·6 ± 0·2	10·3 ± 0·[illegible]
Carbohydrates	18·2 ± 0·9	18·1 ± 1·0
Non-protein nitrogen[b]	0·26	ND[c]
Starch[b]	6·19	ND[c]
Neutral detergent fibre	18·0 ± 0·5	81·0 ± 0·8
Acid detergent fibre	6·4 ± 0·5	66·5 ± 1·1
Hemicellulose	11·6 ± 0·3	14·5 ± 0·7
Cellulose	6·0 ± 0·3	8·1 ± 0·3
Lignin	0·3 ± 0·02	20·2 ± 1·2
Silica	—	1·5 ± 0·01
Cutin	—	34·6 ± 0·9

[a] Mean of four samples.
[b] Mean of two determinations.
[c] Not determined.

corresponds to over 42%. The crude protein and crude fat values of our samples are comparable to those reported by Fetuga *et al.* (1977) for some Nigerian samples. It is of interest to note that the crude protein contents of full-fat kernels are much higher than cereals and similar to those of most tropical pulses (FAO, 1972).

The food energy contents of full-fat kernels were high (Table 1), corresponding to the exceptionally high level of crude fat. The potential level of utilisation of rubber seed lipids by humans or animals has not been studied. However, full-fat kernels are used for human consumption with no reported adverse affects on physical performance (Wheeler, 1978).

The full-fat kernels contained 6·2% starch. Such a low content of starch is a common feature of most oilseeds (Ravindran, 1983). The non-protein nitrogen content (7·56% of total nitrogen) indicates that most of the Kjeldahl nitrogen determined was protein in nature.

The detergent fibre composition was determined due to the current interest in the role of dietary fibre in human nutrition. The values for neutral

TABLE 2
Amino Acid Composition of Rubber Seed Kernels Compared with the NAS/NRC (1980) Reference Protein Pattern (g/16 g N)

	Rubber seed kernels	*NAS/NRC* (1980) *reference pattern*
Aspartic acid	10·1	
Threonine	3·4	4·0
Serine	4·2	
Glutamic acid	14·8	
Proline	3·9	
Glycine	5·3	
Alanine	3·9	
Valine	5·8	4·8
Cystine	1·6	
Methionine	1·2	
Methionine + cystine	2·8	2·6
Isoleucine	3·3	4·2
Leucine	6·9	7·0
Tyrosine	2·6	
Phenylalanine	5·1	
Tyrosine + phenylalanine	7·7	7·3
Lysine	4·4	5·1
Histidine	2·3	1·7
Arginine	9·2	
Tryptophan	1·4[a]	1·1

[a] Value cited from Fetuga *et al.* (1977).

detergent fibre and acid detergent fibre were 18·0% and 6·4%, respectively. Almost 94% of the acid detergent fibre fraction was determined to be cellulose.

The rubber seed shell contained very high levels of crude fibre (Table 1). Cutin and lignin constituted 52·0% and 30·4% of the acid detergent fibre fraction, which is not unexpected of a seedhull. Cutin is the major fibre component of seedhulls (Goering & Van Soest, 1970) and is indigestible even by ruminants. There is no record of any serious attempt to commercially exploit the rubber seed shell. Its potential uses, based on the chemical composition, are probably either as a filler in plastics or as a source of fuel.

The amounts of most amino acids in rubber seed kernels (Table 2) were similar to those reported by Fetuga *et al.* (1977) for samples from Nigeria. Exceptions were aspartic acid, arginine and glutamic acid which were lower, and lysine, which was higher, in our samples. Compared to the reference protein pattern recommended by NAS/NRC (1980), rubber seed kernels were deficient in lysine, isoleucine and threonine. The kernel, however, will supply 75–85% of the recommended requirements for these amino acids.

TABLE 3
Mineral Composition of Defatted Rubber Seed Kernels (Dry Matter Basis)

Major minerals (g/100 g)	
Calcium	0·17
Phosphorus	0·24
Potassium	1·22
Sodium	0·05
Magnesium	0·24
Trace minerals (mg/100 g)	
Iron	18
Manganese	9
Zinc	15
Copper	5

Tryptophan was not estimated in our study, but the value quoted by Fetuga *et al.* (1977) shows that tryptophan may not be deficient. The present results indicate the rubber seed protein to be somewhat imbalanced in nature, which may partly explain the poor protein quality indices generally reported for rubber seeds (Giok *et al.*, 1967; Fetuga *et al.*, 1977).

The Ca and P contents observed (Table 3) are much lower than the levels of 0·88% Ca and 0·94% P reported by Fetuga *et al.* (1977). These discrepancies are probably related to differences in climatic and soil factors. The high content of K and low content of Na in rubber seed kernels is another feature that is noteworthy. It appears that many tropical plant species exhibit a tendency to accumulate K rather than Na (Ravindran & Ravindran, 1987). The values for trace minerals (Fe, Mn, Zn and Cu) are within the normal range reported for tropical pulse seeds (FAO, 1972). These values also compare closely to those reported for rubber seed samples from Nigeria by Fetuga *et al.* (1977).

Because of the extremely high lipid content of rubber seeds, it was thought pertinent to include the published information on the fatty acid profile of rubber seed oil. The data presented in Table 4 show that rubber seed oil is one of the most unsaturated oils that is produced by the plant kingdom. The oil contains over 81% unsaturated fatty acids. In particular, the high content of linoleic acid would be of nutritional advantage as this is an essential fatty acid. In contrast, coconut oil, which is a major edible oil in Asian countries, contains over 90% saturated fatty acids and is said to be highly cholestrogenic (Chong & Mills, 1966). Good grade rubber seed oil may have potential as an edible oil. In India, up to 13% good rubber seed oil has been

TABLE 4
Fatty Acid Composition of Rubber Seed Oil (Percentage by weight of oil)[a]

Myristic acid (C 14:0)	0·1
Palmitic acid (C 16:0)	8·1
Stearic acid (C 18:0)	10·5
Arachidic acid (C 20:0)	0·3
Palmitoleic acid (C 16:1)	0·3
Oleic acid (C 18:1)	21·5
Linoleic acid (C 18:2)	37·3
Linoleic acid (C 18:3)	21·7
Arachidonic acid (C 20:4)	0·2

[a] Data from Orok & Bowland (1974).

added to other oils without any effect on the quality of the resultant cooking oil (Anon., 1903). The practical problems in obtaining good grade rubber seed oil need special mention at this point. Due to the high moisture content of fresh seeds and the inevitable time lapse between seed drop, collection and oil extraction, the lipids quickly undergo enzymatic hydrolysis, resulting in a high acid value. This renders the oil rancid and gives it a varnish-like odour on cooking (Udomsakdhi *et al.*, 1974).

The presence of cyanogenic glucosides in rubber seeds was first studied by Georgi *et al.* (1932). Toxic levels of cyanide (164 mg/100 g dry weight) were determined in our fresh seed kernel samples (Table 5), but the cyanide is known to decline rapidly during the first week of storage (Georgi *et al.*, 1932). In the present study, the cyanide content was lowered to 4·2 mg/100 g dry weight after 3 months of storage time. Cooking of fresh kernels similarly eliminated 93% of the initial cyanide content. These observations suggest that cyanide would not present any particular problems should properly processed seed kernels be incorporated into human diets and animal feeds.

TABLE 5
Levels of Some Anti-nutritional Factors Present in Rubber Seed Kernels (Dry Matter Basis)

Phytic acid P (% of total P)	37·5
Tannins[a]	Trace
Trypsin inhibitor activity	Absent
Hydrocyanic acid (mg/100 g)	
Fresh kernels	164
After 3 months storage	4·2
Fresh kernels after cooking for 30 min	7·8

[a] Rubber seed shells contained 0·92% tannins.

The residual cyanide levels, however, must be viewed with some caution. The cyanide is detoxified in biological systems mainly through combination with sulphur sources (Oke, 1973) and this may increase the requirements for sulphur-containing amino acids in the diets. Thiocyanate, produced during the detoxification process, is a potent goitrogen and has been implicated in the etiology of goitre in animals (Langer, 1966) and humans (Ekpechi *et al.*, 1966).

No anti-tryptic activity was detected in the seed kernel samples. The rubber seed shells contained 0·92% water-extractable tannins, whereas only traces were found in the seed kernels. The phytate P content (37·5% of total P) is within the range reported for cereals and pulses (Reddy *et al.*, 1982). Phytate P is generally regarded as being less biologically available to humans and this may further aggravate the problem of low P in rubber seed kernels. The phytate is also known to reduce the availability of other essential minerals, including Ca, Mg, Zn and Fe (Oberleas, 1973).

Although not determined in our study, the possible presence of phytohaemagglutinins in rubber seeds warrants further investigation. Studies with poultry have demonstrated that rubber seed cake, the residue remaining after the extraction of oil from rubber seeds, has an anti-fertility effect (Buvanendran, 1971; Rajaguru, 1971; Ravindran *et al.*, 1987). Ravindran *et al.* (1987) suggested that this effect may be due to the presence of a phytohaemagglutinin. Their suggestion arises from the report that ricin, the phytohaemagglutinin of the castor (*Ricinus communis*) seed, lowers the *in vitro* fertilisation of ova in hamsters (Oikawa *et al.*, 1973). Whether the above observations are relevant to humans is difficult to assess, but it is not unlikely that a factor causing an anti-fertility effect on animals may also have a similar effect on humans. The isolation and identification of this anti-fertility factor merits future research.

Finally, it is appropriate to highlight some practical limitations with regard to the use of rubber seeds. Rubber seed collection is cumbersome and time-consuming. The collectable harvest depends *inter alia* on the topography of the land, amount of cover crop in the rubber plantation and availability of labour. Poor keeping quality of the fresh seed is another important problem. Due to the high moisture content of the fresh seed, storage at room temperature causes a rapid hydrolysis of the lipids and promotes mould growth. In the present study, almost 50% of the fresh seeds stored at room temperature had mouldy growth within 3 months. The keeping quality was improved when the seed kernels were boiled and dried prior to storage. It was possible to store the dried kernels for 3 months without any noticeable deterioration.

The present results have shown that the seed kernels of para-rubber contain substantial quantities of crude protein and food energy. However, the protein was slightly deficient in lysine, isoleucine and threonine. The kernels were also poor sources of Ca and P and contained relatively high levels of phytate P, suggesting that Ca/P imbalance may be a possibility under practical conditions. Owing to the possible anti-fertility effect and to collection and storage problems, it is concluded that rubber seeds show little promise as a human food in normal times. They certainly have potential during emergency situations. However, the usefulness of rubber seeds as an animal feed, particularly for growing animals, cannot be overemphasised. Further research on the biological evaluation of these seeds is suggested to assess their real potential as animal or emergency human foods. Different processing and storage methods to eliminate or lower the anti-nutritional qualities and to improve the keeping quality of the seeds are other aspects which need to be investigated.

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