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Terminalia catappa Linn seeds as a new food source

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Abstract

To evaluate their potential use as a new dietary source, the seeds of *Terminalia catappa* Linn were analyzed for their nutritional and antinutritional properties, and to determine the effect of roasting. The TC seeds contained high levels of protein, oil and essential minerals. The 2 most limiting amino acids were Tryptophan and Lysine. Oleic acid (C18:1) and linoleic acid (C18:2) are the main fatty acids which were determined at 32.4 and 30.3%, respectively. The ratio of saturated: mono-unsaturated: polyunsaturated fatty acid was close to what is recommended in the dietary guidelines of the American Heart Association. Contents of phenolic compounds and phytates (IP4 + IP5 + IP6) in raw seeds were 64.9 g of GAE/g and 2,110 mg/100g, which are comparable to the values in edible nuts. Trypsin inhibitor activity was 2.3 trypsin inhibitor units/mg. After roasting at 180°C for 4 min, both phenolic compounds and trypsin activity were reduced, while IP6 phytate degraded into IP4 and IP5 forms.

Keywords: fatty acids, protein pattern, antinutritional compounds, roasting

1. Introduction

Terminalia catappa Linn (TC) - belonging to the family Combretaceae - is naturally widespread in the sub-tropical and tropical zones of the Indian and Pacific Oceans, and is planted extensively in many countries as an ornamental tree. Some species of the genus Terminalia have been used as traditional medicines in both East and West African countries to treat infectious diseases (Oliveria *et al*., 2000). Various bioactivity studies of TC leaves and bark extracts have reported them to have anticancerous, antioxidant, anti-HIV reverse transcriptase, anti-inflammatory and hepato-protective effects (Lin *et al*., 1997; Masuda *et al*., 1999; Chen *et al*., 2000; Fan *et al*., 2004). TC fruits extracted by petroleum ether, methanol and aqueous solution possess antidiabetic activity (Nagappa *et al*., 2003). The seed (kernel) of TC also has aphrodisiac properties (Ratnasoosiri and Dharmasiri, 2000).

Most of the research done so far has mainly focused on biological and phytochemical studies from leaves, bark and fruit extracts as a database for medicinal benefit, not in the realm of nutritional benefit. In some countries, especially Thailand, children in some areas eat raw mature TC seeds as a snack (known as Hu-Kwang there), extracted by hitting the mature fruits with a stone or by cutting them with a knife. Although it has been known that the seed is edible, few papers have information on the nutrient content of TC seeds, and no previous studies have investigated TC seeds as a

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new alternative food for human consumption. Oliveria *et al.* (2000) investigated the composition and nutritional properties of a variety of mature seeds, including *T. catappa* Linn, and reported that the protein content of TC seeds is higher than that of seeds of important legumes such as peanuts, lentils, mung beans and chickpeas. In addition, the oil content is comparable to oilseeds such as peanut, rapeseed, and sunflower.

For nutritional evaluation of grains, legumes, nuts and seeds, an antinutritional factor - food poisoning – is a concern. Poisonous substances include trypsin (protease), polyphenol, inhibitors, oxalates, phytates, and haemagluttinins (lectins). Among antinutritional compounds, trypsin inhibitors (TIA) and phytic acid (myoinositol 1,2,3,4,5,6-hexakisphosphoric acid) are of more concern since they occur in a wide range of plants, especially grain, legumes, nuts and oilseeds (Akande *et al*., 2010). The study of TC seeds related to food is still limited, and practically nothing is known about their nutritive value, including their nutrient especially fatty acid profile and amino acid contents and antinutritional composition compared with edible nuts. The present work, therefore, aims to determine the nutrients and antinutritional factors of raw and cooked TC seeds. This information can be used to evaluate the potential application of TC seeds as an alternative food source.

2. Materials and Methods

2.1 Sample preparation

Natural samples of *T. catappa* with partially dried fruits (with gray colored pericarp) were collected from the campus of Naresuan University, Phitsanulok, Thailand, during July-August and October-November. The fruit was cleaned and oven-dried at 60°C for 12 hr. The shell was cracked to obtain the seed (kernel). The seeds were then ground in a coffee grinder (CBG5 series, Black and Decker Canada, Ontario, Canada) for 5 min to a fine powder and stored at -20°C until further analysis. The raw almonds (Heritage™; Heritage Snacks & Food, Nakornpathom, Thailand), cashew nuts (Raitip™; Thai Cereal World, Nonthaburi, Thailand) and peanuts (KhaoThong™; Food Industry (1964), Bangkok, Thailand) were bought from a Makro supermarket (Siam Makro Public Company, Phitsanulok, Thailand). They were directly ground and kept under the same condition as TC fine powder. If to be used for cooking, the TC seeds were first roasted in an oven (House Worth, HWB001, Kyusen, Samutprakan, Thailand) at 180°C for 4 min.

2.2 Proximate and mineral analysis

All samples were analyzed for proximate composition but only TC samples were analyzed for mineral contents. The moisture content of nut/seed powders was determined by the AOAC method (2000); the crude protein content was determined by the Kjeldahl method (N x 6.25); the crude lipid (Soxhlet extraction), crude fibre and ash contents were determined by the gravimetric method employing AOAC methods (2005). Iron, zinc, magnesium, calcium, potassium, and copper were characterized and quantified in triplicate by atomic absorption spectrophotometry (Model 2100, Perkin Elmer, Massachusetts, USA). Phosphorus was quantified by gravimetric method (AOAC, 2005).

2.3 Amino acid pattern

The raw and roasted TC seeds were analyzed for amino acid contents. The quantification of amino acids was performed by acid hydrolysis of proteins and peptides following the derivatization approach (Petritis *et al*., 2002; Bosch *et al*., 2006). Since cysteine (Cys) and methionine (Met) are partially destroyed by acid hydrolysis, they were oxidized with performic acid (Sigma Aldrich, Missouri, USA) to cysteic acid and methionine sulphone prior to acid hydrolysis. Acid hydrolysis was performed with 6 M HCl (5 mL) for 22 hr at 110°C in sealed glass tubes. The derivatization step consisted of esterification with AccQ-flour derivatization buffer and AccQ-flour reagent (Waters, Massachusetts, USA) to yield fluorescent derivatives, allowing amino acid detection at under-picomolar levels. Aliquots were used for analysis by HPLC (Water Alliance 2695 with heater Jasco FP2020 fluorescence detector (EX: 250, EM: 395 nm) by Agilent Technologies, California, USA. Amino acid composition was reported as grams of amino acid per 100 gram of protein, and essential amino acid (EAA) score expressed as percentage was determined by the following formula:

$$EAA\ score = \frac{EAA_{test}}{EAA_{ref}} \times 100 \qquad (1)$$

where EAA_{test} is amount of EAA in test protein and EAA_{ref} is amount of reference EAA pattern according to FAO/WHO report (1991)

2.4 Fatty acid profile

The fatty acids of raw seeds were determined by gas chromatography according to the AOAC method (2005). Fatty acids were obtained by saponification of fats. Then, free fatty acids were esterified by boron trifluoride catalyst. The methyl esters of fatty acids were extracted by petroleum ether. Then they were dissolved with chloroform, and were injected into gas chromatography (Varian 3600, Scientific Equipment Sources, Ontario, Canada) equipped with a flame ionization detector. A GC analysis was performed with the detector temperature programmed for 300°C, flow rate of 2 mL min^{-1} and 250°C injector temperatures. Nitrogen was used as the carrier gas. The identification of the peaks was achieved by comparing their relative and absolute retention times with authentic standards. The ratio of saturated: monounsaturated: polyunsaturated fatty acid (S:M:P) was obtained from the sum of each type of fatty acids and calculated to proportion.

2.5 Antinutritional compounds

2.5.1 Phenolic contents

Total phenolics of the raw and roasted TC seeds were determined on the basis of the Folin–Ciocalteu method (Caboni *et al.*, 1997). Briefly, after extracting the ground samples (3 g) with 80% ethanol (100 mL), the extracts (2 mL) were mixed with 5 mL of Folin–Ciocalteu reagent (Merck, Darmstadt, Germany) and 10 min later, 0.4 mL of sodium carbonate (20% w/v) was added. The mixture was heated to 100°C. After cooling, the absorbance at 750 nm was measured. Gallic acid (Sigma) was used as standard, and results were expressed as milligrams of gallic acid equivalents (GAE) per gram of dry weight sample.

2.5.2 Trypsin inhibitor

Trypsin inhibitor activity (TIA) was examined by a spectrophotometric method of AACC (1991), using α-N-benzoyl-DL-arginine-nitroanilide hydrochloride (BAPNA) as the trypsin substrate. A dried sample (1 g) was extracted with 0.1 N NaOH (50 mL), the suspension was made up to 2 mL with distilled water, and 2 mL trypsin solution (in 0.001 M HCl) was added to each test tube and kept in a water bath at 37°C. To each tube, 5 mL BAPNA solution (Sigma-Aldrich, Missouri, USA, 85711-4; purity $\geq$99%) in dimethyl sulfoxide was added, and the reaction was terminated after 10 min by adding 1 mL acetic acid (30%). After centrifugation, spectrophotometer (UV-Visible spectrophotometer, Shimadzu, Kyoto, Japan) was used to measure the absorbance of the clear solutions at 410 nm against reagent blank (30% acetic acid containing trypsin and distilled water+ BAPNA solution). Trypsin inhibitor activity (TIA) was expressed in terms of trypsin inhibitor units (TIU) per milligram of sample. One trypsin unit was arbitrarily defined as an increase of 0.01 absorbance units at 410 nm per 10 mL of reaction mixture.

2.5.3 Phytate content

The phytates in TC seeds are inositol tetraphosphate (IP4), inositol pentaphosphate (IP5) and inositol hexaphosphate (IP6). Their contents were determined according to the method described by Hotz and Gibson (2001). Briefly, 0.5 g of dried weight sample were ground in a coffee grinder (Kenwood CG 100, Kenwood Electronic, Bangkok, Thailand) and were extracted with 0.67 M HCl (5 mL) for 30 min in an ultrasonic bath (Model 1510E-MT Bransonic, Manchester, United Kingdom). Following centrifugation, the supernatants were diluted with deionized water, and then were applied onto an anion exchange column (WAT023620, Sep-Pak Vac 1 cm^3 Water Accell Plus QMA, Waters, Milford, Massachusetts, USA, and inositol phosphates were eluted with HCl and evaporated to dryness at 40°C in a centrifugal evaporator (Model CVE-2000; EYELA, Tokyo Rikakikai, Tokyo, Japan). The residues were dissolved in deionized water and analysis of IP4, IP5 and IP6 was performed by reverse phase HPLC (Atlantis dC18, 5 mm, and 4.6 x 150 mm^2, Waters, Massachusetts, USA) with refractive index detector (Waters IR 414). The mobile phase was a mixture of methanol: H_2O (3:2) at a flow rate of 0.8 mL min^{-1}.

3. Results and Discussion

It has been known that the seed (kernel) of *T. catappa* (TC) fruit at full maturity is edible; nevertheless, it is not commonly consumed. Previous studies showed that TC seeds are high in protein (29.4 g/100g dry basis) and fat contents (58.3 g/100g dry basis) (Oliveria *et al.*, 2000). Investigating the potential value of TC seeds as a food source, especially nutrient composition, antinutritional compounds, and the effect of heat treatment on their nutritional properties, will be beneficial.

3.1 Proximate composition

The average weight of TC fruit and seed was about 6.3 g and 0.2 g (average of 32 fruits and seeds). The seed is very small so that the percentage yield of seeds was 3.4% of fruit (db). On 100 g dry basis, TC seeds show high nutritional density in minerals which includes calcium, iron, phosphorus, potassium, magnesium, copper and zinc, and have a higher mineral content compared to almonds and peanuts. Considering the nutritional importance of essential trace elements such as copper and zinc because of their essentiality in biological systems, and considering that there are limited amounts of these elements in plant foods, TC seeds can be considered to be a potentially valuable food source of minerals. The protein content of TC seeds (23.3 g/100 g dw) is comparable to almond protein content (23.8 g/100 g dw), and statistical tests show that TC seed protein content is similar ($p<0.05$) to almonds, higher than cashews, but lower than peanuts (Table 1). Fat content of TC seeds is significantly higher ($p<0.05$) than that of nuts (60.0 g/100 g dw).

3.2 Protein pattern

Despite the small size of TC seeds, their amino acid contents are comparable with the nuts based on 100 g protein levels (Table 2). Like the amino acid profiles of almonds, peanuts and cashews, the predominant amino acids in TC seeds are glutamic acid (20.5 g/100 g protein) followed by arginine (15.8 g/100 g protein). L-arginine is a semi-essential amino acid that promotes a healthy cardiovascular system since it is a precursor of nitric oxide (NO) which plays an important role in many bioactivities including vasodilatation, antiplatelet effect and antioxidant activities (Wells *et al.*, 2005).

Like almonds, peanuts and cashews, TC seeds have a lower level of essential amino acids compared to whole egg, but at similar level to one another. TC seeds contain the highest sulfur-containing amino acid (Met + Cys) 3.7 % of

Table 1. Proximate composition and mineral contents of raw *Terminalia catappa* seeds compared with almonds, peanuts and cashews.

Component	TC seeds (dry basis)	Almonds (dry basis)	Peanuts (dry basis)	Cashews (dry basis)
Moisture (g/100g)	4.3±0.1	5.9±1.0	7.8±1.8	3.3±1.6
Protein (N x 6.25) (g/100g)	23.3±1.4	23.8±0.9	31.1±1.4	19.0±1.2
Oil (g/100g)	60.0±0.1	55.7±1.0	43.4±0.1	50.1±6.4
Ash (g/100g)	4.2±0.3	3.1±0.3	2.5±0.1	2.3±0.2
Total carbohydrates (g/100g)	12.5	17.5	22.9	28.5
Crude fibre (g/100g)	8.5±1.7	6.2±1.1	4.5±0.6	1.3±0.6
Minerals (mg/100g)				
Calcium	325.2±0.3	248 [1]	32.7 [2]	-
Iron	5.4±0.3	4.3 [1]	1.9 [2]	-
Phosphorus	889.9±7.6	474 [1]	856.3 [2]	-
Potassium	731.1±5.2	728 [1]	668.1 [2]	-
Magnesium	364.7±2.4	275 [1]	190.5 [2]	-
Copper	2.5±0.1	1.1 [1]	-	-
Zinc	6.1±0.3	3.4 [1]	4.3 [2]	-

The data are reported as mean ± standard deviation (SD).
TC - *Terminalia catappa*
Total carbohydrates were calculated by difference (100 % - percentage of sum of protein, fat, ash and moisture)
[1] Alexiadou and Katsilambros (2011) [2] de Oliveira Sousa *et al.* (2011)

total amino acids followed by cashew nuts (2.8%), peanuts (1.6%) and almonds (1.1%) as indicated by Venkatachalam and Sathe (2006). Sulfur-containing amino acids are essential for the entire biological system such as the synthesis of essential bio-molecules like antioxidants such as glutathione, thiamine, biotin, coenzyme A (Wirtzl and Droux, 2005).

There were minimal losses of all amino acids from roasting at 180°C for 4 min except arginine (34% loss) and phenylalanine (34% loss) and almost all EAA are above the suggested pattern of requirement by FAO/WHO with the exception of tryptophan, histidine, threonine, and lysine. Regarding the EAA score of roasted TC seeds, the lowest and the highest were 9% of tryptophan and 149% of valine. Venkatachalam and Sathe (2006) reported tryptophan to be the first limiting essential amino acid in nuts including macadamias, pecans and pistachios, while Ruggerinet *et al.* (1998) found that lysine was the first essential amino acid in almonds, hazelnuts, pecans, pistachios and walnuts. Like the nuts, the first and second limiting essential amino acid of TC seeds are tryptophan (EAA score 9%) and lysine (EAA score 42%). To provide adequate amounts of all essential amino acids in terms of food application, TC protein should be combined with other incomplete proteins such as the protein of food legumes (mungbean, soy bean and lentil), which are a relatively rich source of lysine and tryptophan but are low in sulphur amino acids, to form a complementary and complete protein.

3.3 Fatty acid profiles

The fatty acid compositions of TC seeds compared with four other vegetable oils coconut, palm, sesame and soybean oil are presented in Table 3. The data show that TC seeds mainly consist of unsaturated fatty acids with a percentage of 63.9, and the most abundant unsaturated fatty acids are oleic acid (C18:1) (32.4%), followed closely by linoleic acid (C18:2) (30.3%), indicating that TC oil is a good source of essential fatty acids and is of good quality. However, TC seed contains oleic acid (32.4%) and total monounsaturated fatty acid (MUFA) (33.5%) lower than sesame oil (41.1% and 41.4%) and palm oil (38.8% and 38.9%). The appreciable concentration of MUFA makes them desirable in term of nutrition (Corbett, 2003). Many studies suggest that high intake of MUFA has been associated with protection against coronary heart disease. A diet rich in polyunsaturated fatty acid (PUFA) like linoleic causes LDL particles to be more susceptible to oxidation than a diet rich in MUFA since linoleic is more susceptible to oxidation than oleic acid.

Total saturated fatty acid (SFA) content of TC seeds is higher than that of soybean oil, but lower than that of coconut and palm oil. Similar to palm, sesame and soybean oil, palmitic acid (C16:0) is the predominant saturated fatty acid (30%) in TC seeds followed by stearic acid (C18:0) (6%). The palmitic acid (C16:0) content of TC seeds is the higher

Table 2. Amino acid composition of raw and roasted *Terminalia catappa* seeds compared to raw almonds, peanuts, cashews and whole egg protein, and to the FAO/WHO[1] reference pattern for the essential amino acids.

Amino acid	TC seeds	Roasted TC seeds	Almonds[2]	Peanuts [2]	Cashews [2]	Whole Egg protein	FAO/WHO pattern[1]	*EAA score[3]*
				(g/100g protein)				
Ile*	3.5 ± 0.2	2.8 ± 0.4	3.9	3.5	4.2	6.3	2.8	102
Leu*	8.1 ± 1.8	7.5 ± 0.2	7.2	7.0	8.0	8.8	6.6	114
Phe*	5.3 ± 0.3	3.5 ± 0.4	5.5	5.4	4.8	5.7	6.3[a]	104
Lys*	2.4 ± 1.0	2.4 ± 0.2	3.1	3.9	4.6	7	5.8	42
Thr*	3.2 ± 0.2	2.1 ± 0.4	2.6	2.2	3.2	5.1	3.4	61
Val*	5.0 ± 0.3	5.2 ± 0.1	4.4	3.9	5.7	6.9	3.5	149
Arg*	15.8 ± 0.4	10.4 ± 0.1	10.1	11.1	9.8	6.1	-	-
His*	1.8 ± 0.1	2.1 ± 0.2	2.9	2.5	2.7	2.4	1.9	109
Met	1.0 ± 0.2	1.6 ± 0.1	0.8	1.3	2.3	3.4	2.5[b]	146
Trp	0.1 ± 0.0	0.1±0.1	0.7	0.7	1.3	1.7	1.1	9
Cys	3.1 ± 0.1	2.1 ±0.0	0.3	0.3	0.5	–	5.9	
Ala	4.2 ± 0.3	2.8 ± 0.2	4.9	4.8	4.5	–	5.9	
Asp	8.5 ± 0.4	7.8 ± 1.1	9.2	12.1	8.55	–	9.6	
Glu	20.5±3.2	15.5 ± 0.4	26.8	21.1	22.4	–	12.7	
Gly	6.3 ± 0.1	5.4 ± 1.0	6.9	6.4	4.6	–	3.3	
Pro	4.1 ± 0.3	5.5 ± 0.0	5.1	5.8	5.4	–	4.2	
Ser	4.3 ± 0.2	3.4 ± 0.5	3.7	4.8	5.2	–	7.6	
Tyr	2.8 ± 0.5	3.1 ± 0.7	2.2	3.4	2.4	–	4.2	

Data of TC seed samples are reported as mean ± standard deviation (SD).
*Essential amino acids
[1]FAO/WHO recommended pattern for 2-5 year old children is given(1991).
[2] Venkatachalam and Sathe (2006)
[3]EAA score is given roasted seeds based on FAO/WHO recommended pattern.
a - Phynylalanine + tyrosine, b - Methionine + cystine.

than coconut, sesame and soybean oil, but lower than palm oil. Palmitic acid (C16:0) is number two among three types of cholesterol-raising saturated fatty acids lauric acid (C12:0), palmitic acid (C16:0) and myristic acid (C14:0) (Grundy, 1997; Wahrburg, 2004).

It has been accepted that PUFA has a positive impact on the LDL/HDL ratio, reducing the risk of heart disease. However, the effects of lipids on the heart are not dependent only on the types, but also on their content in terms of proper balance of fatty acid ratio. According to the fat dietary guidelines of the current National Cholesterol Education Program (NCEP) and American Heart Association (AHA) the heart health promotion by dietary fat, besides the importance of limiting fat intake overall, the optimum fatty acid balance (ratio of SFA to MUFA to PUFA) is recommended at approximately 1:1:1 or 1:1.5:1 to keep the best LDL/HDL ratio (Hayes, 2002). Significant deviation from optimum fatty acid ratio such as too-low SFA or too-high MUFA or PUFA induces an undesirable lipoprotein profile. The fatty acid balance of TC seeds 1:0.9:0.8 for SFA: MUFA: PUFA is close to the fat dietary guideline of NCEP and AHA compared with other vegetable oils (Table 3).

Although the percentage of seed yield is low (3.4%), the seeds contain a high fat content (60%). With respect to individual fatty acid results that S:M:P is close to fat dietary guideline, the oil of TC seeds is a good alternative edible oil due to the optimum fatty acid balance and consumption of the oil requiring no complement with other oils.

3.4 Antinutritional compounds

Some antinutritional properties such as phytate, trypsin inhibitor, goitrogen, antivitamin factors, and tannin are heat-labile, while others such as alkaloids, flavonoids, saponin and oxalate are heat-stable. There are no data available on the effect of heat treatment on trypsin inhibitor activity (TIA), phytate content (myo-inositol phosphate) and phenolic content in TC seeds. We determined total phenolic contents of TC seed comparing with almond, peanuts and cashew nuts. The present study shows that total phenolics of TC seeds (51.1 mg GAE/g dw) is comparable to peanuts (48.7 mg GAE/g) and cashew nuts (45.2 mg GAE/g) after roasting

Table 3. Fatty acid profile of TC seeds compared with other vegetable oil

Fatty acids	TC seeds	Coconut oil [1]	Sesame oil [1]	Soybean oil [1]	Palm oil [1]
	(g/100g oil)				
Saturated					
C6:0	0	0.5	0	0	0
C8:0	0	8.0	0	0	0
C10:0	0	6.3	0	0	0
C11:0	0	0	0	0	0
C12:0	0	48.5	0	0	0.3
C14:0	0.1	17.6	0	0.1	1.1
C16:0	30.0	8.4	9.9	11	45.1
C 17:0	0	0.1	0.0	0	0
C18:0	6.0	2.4	5.2	4.0	4.7
C19:0	0	0	0	0	0
C 20:0	0	0.1	0	0.3	0
C22:0	0	0	0	0.1	0
C24:0	0	0.1	0	0	0
Total	36.1	92.0	15.1	15.5	51.2
Monounsaturated					
C14:1	0	0	0	0	0
C16:1	0.4	0	0.3	0.1	0.1
C18:1	32.4	6.5	41.1	23.4	38.8
C20:1	0.7	0	0	0	0
Total	33.5	6.5	41.4	23.5	38.9
Polyunsaturated					
C18:2	30.3	1.5	43.3	53.2	9.5
C18:3	0.1	0	0.2	7.8	0.4
Total	30.4	1.5	43.5	61.0	9.9
U/S	1.8	0.1	5.6	5.5	0.9
S:M:P	1:0.9:0.8	1:0.07:0.02	1:3:3	1:2:4	1:0.8:0.2

[1] Data from Chow (2005)

U/S - Unsaturated fatty acids/saturated fatty acids

S: M: P Saturated fatty acid: Monounsaturated fatty acid: Polyunsaturated fatty acid

at 180°C for 4 min, and roasting caused 21% loss of total phenolic content (Table 4). Although phenolic compounds such as tannin, chlorogenic acid are classified as antinutrients, they possess a benefit in terms of reducing the risk of degenerative chronic diseases due to their antioxidant, anti-cancer, anti-inflammation and anti-bacterial activities.

Generally, inositol hexaphosphate (IP6) is a major form of phytate in raw food, and many data has indicated that those inositol phosphates in the forms of inositol mono-, di-, tri- and tetraphosphates (IP1, IP2, IP3, and IP4) have no detrimental effect on mineral absorption probably due to their lesser capacity to bind metal ions as well as the more soluble complexes (Phillippy *et al*., 2004). Nevertheless, IP5 and IP6 have stronger inhibitory effects on micro-nutrient absorption than the other inositol forms (Sandberg *et al*., 1999). By anion-pair reverse phase high-performance liquid chromatography measurement, the initial total phytate content (IP4+ IP5+IP6) in TC seeds was 2,111.8 mg/ 100g dw. The phytate content of TC seeds was comparable with peanuts (170-4, 470 mg/100 g dw), almonds (350-9,420 mg/100g dw) and cashew nuts (190-4,980 mg/100 g dw) (Schlemmer *et al*., 2009). According to Sandberg and Anderine (1986), phytate elimination or reduction means to degrade IP6 into other forms of phytate. Roasting is applied to represent heat treatment because it is a basic traditional dry heat widely used for a common nut/seed snack. Roasting the TC seeds at

Table 4. Nutrient and antinutritional components of raw and roasted seeds of Terminalia catappa in dry basis

Components	Raw seeds	Roasted seeds*
Protein (%)	19.8±0.4[a]	19.2±0.1[a]
Fat (%)	55.1±1.1[a]	53.5±0.4[a]
Ash (%)	4.9±0.1[a]	4.8±0.1[a]
Total phenolics (mg GAE/g)	64.9±2.6[a]	51.1±6.7[b]
Trypsin inhibition activity (TIU/·mg)	2.3±0.4[a]	1.6±0.1[b]
Inositol hexaphosphate (IP6) (mg/100 g)	1,762.71±8.39[a]	1,508.82±10.19[b]
Inositol pentaphosphate (IP5) (mg/100 g)	299.40±1.06[a]	600.68 ± 3.40[b]
Inositol tetraphosphate (IP4) (mg/100 g)	48.87± 0.61[a]	166.56 ± 0.85[b]

* Roasting at 180 °C for 4 minutes.
Data are reported as mean ± standard deviation (SD).
Means within each row with different letters (a, b) are significantly ($P<0.05$) different.
Total phenolics are expressed as milligrams gallic acid equivalents per gram of sample.
The contents of protein and fat are differ from Table1 due to the seasonal variation of sampling.

180°C for 4 min decreased the IP6 level while increasing the IP 4 level and the IP5 level (Table 4).

Trypsin inhibitor (TI) occurs naturally in many plant foods, notably soybean and peanut, and may reduce protein digestibility and cause hypertrophy of the pancreas (Liener, 1994). Heat treatment is widely used to inactivate TI, improving nutritional quality. The current result indicates that trypsin inhibitor activity (TIA) of raw seeds was initially 2.3 TIU/mg sample, and was reduced by 29% by roasting.

This study showed that roasting treatment reduced the antinutritional factor phytate, trypsin inhibitor, and phenolic content, but did not alter nutritional content including the protein, fat and ash.

4. Conclusions

The current results show that *Terminalia catappa* seeds contain considerable amount of minerals comparable to widely-consumed nuts. Heat treatment by roasting the seed causes reduction of amino acid, IP6, trypsin inhibitor activity and phenolic compound value. The seeds have a lower level of essential amino acids compared to whole egg. Their fatty acid profile exhibits an optimum ratio of S: M: P according to the fat dietary guideline of the current National Cholesterol Education Program (NCEP) and American Heart Association (AHA), but the health beneficial substances such as tocopherol, tocotrienal and phytosterol, and long term toxicity test of TC oil are required to support the possibility of being dietary oil. The results on TC seeds make them as an important plant source database in literatures.

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