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Availability and Potential of Local Biomass Resources as Fuel for Drying of Tropical Fruits in Northern Thailand

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Abstract

The Thai economy is highly dependent on agricultural exports, including dried fruits requiring large amounts of energy for processing. The main drying technology used in Thailand so far is the convection dryer operated with petroleum fuels. Small-scale farmers relying on these dryers are being impaired by fuel consumption and the increasing costs resulting from deregulated fuel prices. Renewable energy has recently received increased attention from the Thai government with some promising potential. Biomass is a locally abundant renewable resource, a supply of which for fuelling the dryers is already available from production and processing of crops. Fruit production wastes such as pruning wood, seeds, and peels are currently under utilized and could provide a sustainable source of energy for drying. However, the combustion of these resources on an extensive scale requires that their availability and fuel properties should first be known. Currently, little information exists concerning the potential and characteristics of mango, litchi and longan biomass, three crops common in Northern Thailand.

The objective of this study was to investigate wood and processing residues of mango, litchi and longan and their availability and potential as energy sources. Structured interviews as well as laboratory analyses of physical and chemical properties of collected samples were conducted. Fuel property analyses included moisture, ash, fixed carbon, volatile and calorific contents, as well as density. The results showed that the studied biomass is widely available, with pruning wood currently being used to some extent and wastes from processing facilities being mainly dumped. However, as orchards can sometimes be distant from drying facilities, distances between locations may present limitations. Regarding fuel properties, many of the analyzed samples had promising potential. Longan wood showed the maximum heating value per volume, due to its high density. Litchi wood exhibited similar values. Litchi peel and mango seed were the residues with the greatest heating value. Other seed and peel samples had lower energy contents, but were still considered adequate to use as renewable energy sources. High initial moisture content and loose nature of processing wastes may require modification prior to combustion.

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Introduction

In most Asian countries, biomass is an important source of energy representing about 40% of total energy consumption (KOOPMANS & KOPPEJAN 1998; HULSCHER 1998). Substantial amounts of wood fuels, charcoal and other types of biomass such as agricultural residues, dung and leaves are used as energy sources by households and industries. In Thailand for example, biomass has been the traditional source of energy for decades and finds application in both domestic and agricultural industries, especially in rural areas (YOKOYAMA ET AL. 2000; GARIVAIT ET AL. 2006). Reports indicate that the biomass share of total energy consumption for Thailand is 26%, of which wood fuels contributes up to 19% (FAO 1997). However, many potential resources are currently under utilised or end up in landfills (PRASERTSAN & PRASERTSAN 1996).

Among promising renewable energy resources are pruning wood from orchards and residues such as peels and seeds from fruit processing. However, to effectively use biomass as energy, information concerning supply chains, quantity, quality and availability is of great importance (RYAN & OPENSHAW 1991). The design and operation of systems for direct combustion of biomass highly depends on biomass characteristics such as heating value, moisture content, elemental composition and ash content (NORDIN 1994). Very limited documentation exists on fruits typically grown and processed in Thailand.

For this research, production residues from three fruit crops particularly frequent in northern Thailand, mango (*Mangifera indica* L.), litchi (*Litchi chinensis* Sonn.) and longan (*Dimocarpus longan* Lour.), were studied. The aim was to assess their fuel properties and availability as energy sources for potential application as direct combustion fuels. The resulting fundamental information would then form a basis for further research in the practical application.

		
Longan tree, pruning wood and processing waste	LPG-fuelled Dryer	Wood-fuelled Dryer

Materials and Methods

Fruit producers and processing facilities were randomly selected with the prerequisite that the respondent had to be either a farmer or processor of mango, litchi and/or longan. A semi-structured questionnaire was used to collect data from twelve farmers on pruning practices and current uses of pruned biomass. A structured questionnaire was used to obtain information from processing facilities (nine large- and four small-scale) concerning waste generation and management. Measurement of field pruning was done in orchards by randomly selecting recently pruned trees and measuring the fresh weight and diameter of the wood. For determination of fuel properties, wood specimens of varying diameters were collected from orchards and processing wastes were sampled from facilities. For the pruning study, the focus remained in the greater Chiang Mai area, while the processing facilities were scattered over a region encompassing several provinces in Northern Thailand. Samples were analyzed according to methods in Table 1. Proximate analysis was performed with milled samples dried at 60° C for 24 hours.

Table 1. Methods used for determination of fuel properties

Parameter	Unit	Procedure	Standard
Physical Properties			
Moisture content	% w.b.	Gravimetrically by Oven Method	ASABE S358.2
Density	kg/m^3	Displacement Method	ASABE S269.4
Proximate Analysis			
Higher heating value	MJ/kg	Oxygen Bomb Calorimetry (Parr 1108)	ASTM D2016-93 ASTM E711-87
Ash Content	%	Muffle furnace at 575 ± 25° C for 24h	ASTM E1755-01
Volatile Matter	%	Muffle furnace at 950° C for 7 min, in the absence of excess oxygen	ASTM E897-88
Fixed Carbon	%	Calculation (= 100 – Ash – Volatiles)	ASTM E897-88

Results and Discussion

Pruning Wood

Results from farmer interviews revealed that pruning is done annually on young orchards and every two or more years on older orchards (>10 years), all of which are predominately single crop. Pruning was mainly done using the “open-centre” technique and the degree of pruning could be divided into soft (light) and hard (heavy), with only the latter producing definite amounts pruning wood. The most common use of pruning wood is as cooking fuel, with leaves and twigs being used as mulch and fertiliser. In many cases, pruned biomass is disposed of by burning in the field. The diameter of pruning wood ranged between 10 to 150 mm, weight of pruning wood per tree ranged 6-60 kg/tree. Figure 1 indicates the calculated average dry mass of pruning wood during the 2007 season. Size distribution and weight of pruning wood per tree was most dependent on farmer practices, as opposed to age of the trees.

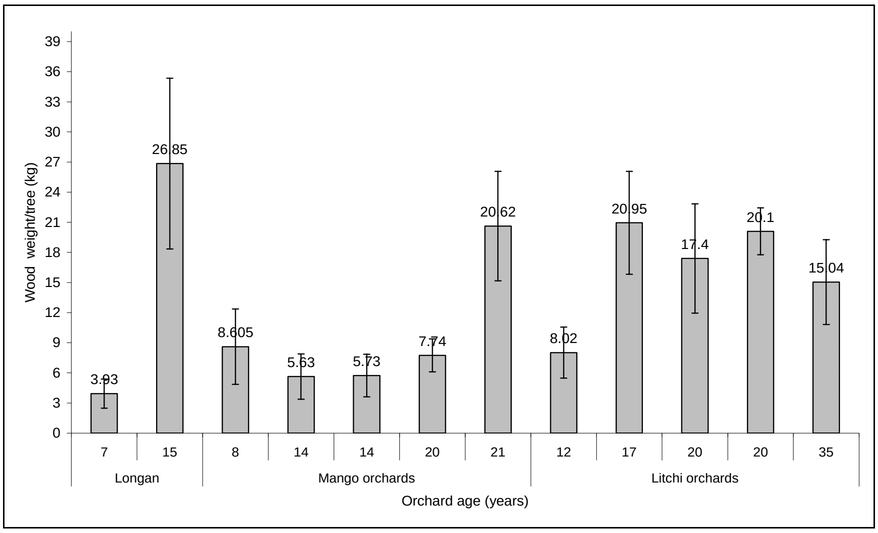

Figure 1: Measured pruning wood generated per tree in 2007

Though results give a positive picture on the potential availability of pruning wood, KLASS (1998) observed that it is difficult to accurately assess the amount of orchard residues which can be realistically collected and utilised. For example, the severity and frequency of pruning was entirely a subjective decision of the farmer and no correlation between orchard age and the amount of wood was found. Personal opinions about benefits of pruning are believed to be the main factor affecting pruning practices of individual farmers. Furthermore, labour requirements often determine the frequency and degree of pruning. The sometimes distant proximity of orchards to processing facilities (up to 70 km) also has to be considered as a possible limitation.

Table 2. Fuel properties of pruning wood samples

	H_2O Content (% w.b.)	Density (kg/m^3)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Heating Value (MJ/kg)	HV/ Volume (GJ/m^3)
Mango	50.9 ±2.4	451 ±28	2.07 ±0.36	82.7 ±0.9	15.3 ±0.9	18.7 ±0.8	8.46
Litchi	45.9 ±2.4	591 ±28	2.02 ±0.35	77.8 ±1.8	20.1 ±2.1	18.4 ±0.8	10.87
Longan	41.2 ±2.1	621 ±24	3.68 ±0.52	77.9 ±0.89	18.4 ±1.2	17.7 ±0.4	11.02

Concerning fuel properties (Table 2), longan wood expressed higher density and lower moisture content compared to mango. Litchi had high density and intermediate moisture content. This trend supports the argument that density and moisture content are inversely related (KLASS 1998). On the other hand, the higher ash content in longan suppressed its heating value, but longan had a higher heating value per volume. Overall, the three crops produce wood with relatively low ash content and high volatile matter/heating value, meaning good fuel potential.

Processing Wastes

Theoretically, the abundance of waste stock is substantial, as northern Thailand has an extensive number of fruit processing facilities. From the survey results, processing facilities generated considerable amounts of waste annually, but samples collected had a large variability in moisture content (35 to 73%). If 60% moisture content is assumed, small-scale facilities produce about 30 tons and large-scale facilities produce about 2,200 tons fresh matter annually, on average (Table 3). More than 90% of the waste from large-scale facilities was considered as worthless and dumped at a financial cost in terms of municipal fees and transportation. A sizeable amount of processing waste from small-scale facilities is utilised to make organic fertiliser.

Table 3. Results of the fruit processing facility survey

Fruit Processing Facility	Large Scale	Small Scale
Raw fruit input (tons/day)	30.2 ± 19.2	1.3 ± 0.6
Processing time (days/year)	48.9 ± 8.0	55.0 ± 12.6
Estimated waste (tons/yr)	2,179	29

Similar to wood samples, longan peels had higher ash content compared to mango and litchi, but ash content of the seed was low. Litchi peel and mango seed showed the best potential in terms of heating value (Table 4). Processing wastes from all three crops showed considerably better fuel properties in terms of ash content, volatile matter and higher heating value than other agricultural wastes studied in Thailand such as wastes from paddy, maize, sugarcane and palm (GARIVAIT ET AL. 2006). The close proximity of processing facilities to drying operations is also considered an advantage, especially in cases where the two procedures occur at the same facility. However, high moisture content and “loose” nature of fresh wastes might inhibit their potential as fuels.

Table 4. Fuel properties of processing wastes

	H_2O Content (% w.b.)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Heating Value (MJ/kg)
Peel					
Mango	72.9 ±2.8	3.9 ±0.3	80.9 ±0.7	15.1 ±0.8	18.6 ±0.2
Litchi	62.3 ±1.9	3.9 ±0.1	77.5 ±3.1	18.6 ±3.7	19.6 ±0.1
Longan	56.6 ±2.4	4.2 ±0.8	77.7 ±0.6	18.1 ±0.8	17.3 ±0.1
Seed					
Mango	51.4 ±2.4	2.5 ±0.2	78.2 ±0.7	19.22 ±0.7	19.1 ±0.3
Litchi	59.9 ±4.0	2.1 ±0.1	75.4 ±1.3	22.49 ±1.3	18.1 ±0.1
Longan	35.1 ±2.7	1.9 ±0.6	80.9 ±0.6	17.16 ±0.4	17.7 ±0.1

The most practical solution to problems associated with the raw processing wastes might be solar drying and densification of wastes at specially designated facilities that would act as distributors for these fuels. A practical business could be made by collecting the waste from the processing facilities and then selling it as fuel to drying facilities after modification. Optimally dried and sized waste materials could then be used combustion fuel and the residual ash could still be later applied as fertiliser. A combustion system for these specific wasted would be required for their proficient use as fuels. Briquetting the wastes might also facilitate efficient combustion of the feedstock, while reducing pollutant emissions (GROVER & MISHRA 1996).

Conclusions

Theoretically, there is a considerable potential of production residues from mango, litchi and longan as renewable energy resources in northern Thailand due to their availability and fuel properties. However, more research is necessary on the actual pruning wood available for use as industrial fuel, due to its alternative uses and sometimes distant production proximity to drying facilities. Processing wastes of the three crops in particular showed an excellent advantage over other agricultural residues available in Thailand. Dehydration and further modification of processing wastes also have to be considered. Furthermore, combustion systems for the specific wastes, based on their fuel properties, would also be required. The economic feasibility of using biomass from mango litchi and longan as energy resources needs further investigation as well.

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