Cassava Industry in Thailand: Prospects

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Abstract

In Thailand, cassava (*Manihot esculenta* Crantz) is considered one of the most important economic crops with annual production of around 25 million tons. The production of cassava has steadily increased, mainly through an increase in root productivity (from 15.63 tons/ha in 2001 to 22.93 in 2007). Cassava is grown not only as a subsistence crop by small farmers, but also as an agro-industrial crop with a well-developed industry and market. The starch-rich roots of cassava have been used as a raw material for producing a lot of high value-added products including starch, modified starch, sweeteners and derivatives for food and non-food applications. More recently, since Thailand is a net energy importer, cassava has been developed as an energy crop, producing bioethanol as an alternative fuel. To sustain both food and fuel demand, an increase of root productivity by applying good agricultural practices and varietal improvement has been intensively conducted in Thailand. In addition, the country needs to further develop starch production and products. A zero-discharge process will help minimize resource consumption and wastes. Meanwhile, higher value cassava products will be driven by an increasing need for health and biomaterial products.

Keywords: *Manihot esculenta*, productivity, starch, bioethanol, food additives, renewable energy, zero-discharge, tapioca, biomaterials

Cassava as a Cash Crop of Thai Farmers

Cassava (*Manihot esculenta* Crantz) or tapioca is the third most important economic crop in Thailand. It was first introduced into the southern part of Thailand from Malaysia during the 17^{th}-18^{th} centuries. The crop has excellent drought tolerance and can be planted, with low input requirements, in almost all

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soil types where other crops cannot be cultivated economically. These features led to rapid expansion of cassava planting throughout the country, especially in the Northeastern and Eastern part of Thailand. Currently, a total area of 1.1 million hectares is devoted for cassava planting by a large number of farmers, generating greater than 25 million tons of roots annually (Figure 1). Interestingly, the root productivity of cassava plants in Thailand has been significantly improved almost by 50% (from 15.63 in 2001 to 22.93 tons/ha in 2007), attributable to the employment of improved varieties and good cultivation practices, operating under the collaboration of many government agencies (Department of Agriculture, Ministry of Agriculture and Cooperatives; National Science and Technology Development Agency, Ministry of Science and Technology; Kasetsart University) and the private sector, led by the Thai Tapioca Development Institute (TTDI). Up to now, cassava root productivity in Thailand is the highest amongst the world-leading root producers including Nigeria, Brazil and Indonesia (root production = 44.5, 26.7 and 21.6 million tons, respectively with the world production of 232.5 million tons; root productivity = 11.80, 14.14 and 18.09 tons/hectare, respectively with the world average of 12.45 tons/hectare). With improved root productivity in association with higher root prices, farmer's income per one *rai* (6.25 *rai* = 1 hectare) has increased by 300% from 1,700 Baht in 2001 to 6,900 Baht in 2010. Due to its excellent agronomic traits, improvement in root productivity and increased prices, cassava is now recognized as a cash crop that can generate more revenue for Thai farmers.

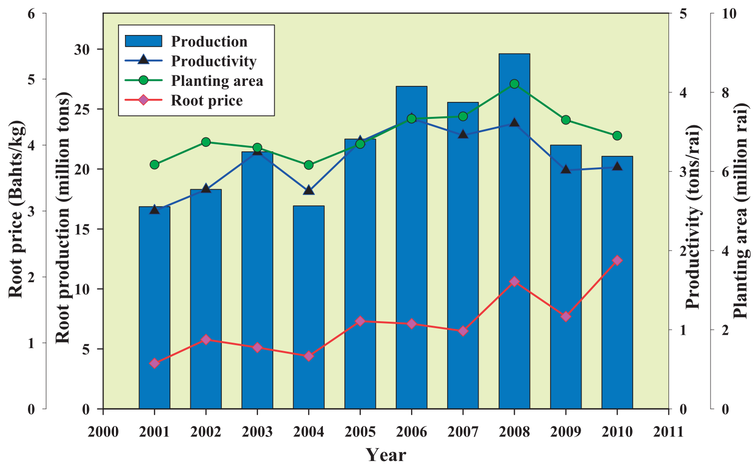

Figure 1. Cassava planting area, root production, root productivity and prices in Thailand for the period 2001-2010.

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Beyond the Farmer's Cash Crop, Cassava is an Industrial Crop

Cassava with edible roots high in starch content (around 70-80% of dry weight) is recognized as an important subsistence food crop for an estimated 500 million farmers globally. In some cassava growing areas such as Nigeria, Ghana and Brazil, the starch-reserved roots are used as the main staple food in the form of fresh roots or as dried cassava flour. Unlike those countries, Thailand has utilized cassava as an industrial crop, with a well-developed industry and market. The industrialization of cassava processing in Thailand has extended from primary products such as chips and pellets to high value-added products which are starch and starch derivatives including tapioca pearls, modified starch, sweeteners, organic acid, sugar alcohols and alcohols. These primary and value-added products are supplied for both local and export markets.

With Market-Oriented Technology Development, Thai Cassava Industry has Greatly Expanded

Cassava chip industry

Cassava chip factories are small-scale enterprises which belong to farmers or small businessmen and are located in close proximity to the growing area. The chipping factories are installed with simple equipment, consisting mainly of a chopper. Roots are loaded into the hopper of the chopping machine by a tractor; after chopping into small pieces, the chips are sun-dried on a cement floor. The final moisture content of chips should be below 14% and the sand content should not exceed 3%. Normally it takes 2.00-2.50 kg of fresh roots (with 25% starch content) to produce 1 kg of chips (14% moisture content). Chips are sold to pelletizing manufacturers who either directly export the chips/pellets or sell to traders. In most cases, the small chip factories sell their products to large factories that in turn sell a consolidated consignment to pellet manufacturers. Some portions of cassava chips are used locally for animal feed, as well as feedstock for producing bioethanol, an environmentally friendly, alternative energy for liquid fuel use as a blend with gasoline, i.e. gasohol in the transportation sector. In addition, the biofuel program being established in some countries, in particular China, has driven a marked increase in the export volume of cassava chips. As the high starch content of cassava chips is of value for biotechnological conversion, the demand for chips for this industry is still very promising.

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Cassava pellet industry

The pellet industry began a few years after Thailand started exporting chips to the EU. The development of this product was stimulated by the need to improve the uniformity in shape and size of cassava chips required by the compound feed producers/users. In addition, during transportation of chips, dust is generated and causes serious air pollution. To overcome this, chips are transformed to pellet form so that less dust is created during loading and unloading. Production of pellets involves pressing chips and extruding through a large die. The heat and moisture in the chips helps in forming a rod-like product, known as a soft pellet. Later process development involves grinding of chips followed by steam extrusion; this creates strong pellets upon cooling, known as hard pellets which are virtually the only pellets exported to Europe.

Cassava starch and starch-based industries

The early stage of cassava starch industry development in Thailand involved mostly cottage-scale factories. The process involved grating fresh roots, mixing with water, followed by sedimentation and sun-drying (or conductive heating), the produced product was traditionally named as "cassava meal" or "cassava flour". Demand for cassava starch increased dramatically and subsequently this led to the development of the modern starch manufacturing process in Thailand. Currently, there are 79 modern starch factories, operating with mechanized processes for separation (e.g. dewatering centrifuge) and drying (e.g. flash dryer) with the total starch production of 15-17 million tons annually (production capacity of 23,500 tons starch/day). The processing time (from grating of fresh root to drying starch) is estimated to be less than 30 minutes. Around 50% of produced starch is used domestically and the rest is for export markets in diversified forms including native, modified and hydrolyzed (e.g. sweeteners, sugar alcohols, amino acids, organic acids). Future exports of cassava starch are expected to increase due to the growth of the global industrial sector and starch markets.

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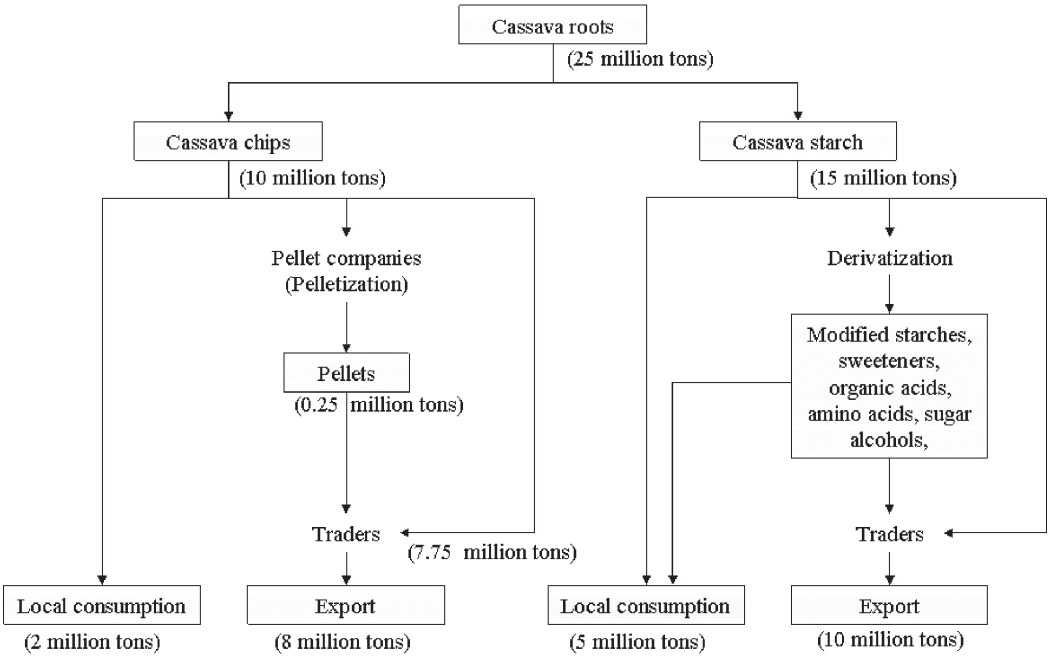

Figure 2. Diagram illustrating the division of root stock use and final products.

Challenges to the Thai cassava industry

Although the Thai cassava industry has long been developed and has become one of the most competent agri-business and agro-industries compared to other crops, the industry is still confronted with a lot of rapid and dynamic changes, e.g. climate change, depletion of natural resource reserves, national vs international trading policy and regulations, modernization in industry, consumer behavior and needs. These constraints are an important driving force that directs the development of the industry.

Sustainability of food and fuel security

In addition to being both a food crop and an industrial crop, cassava has recently been considered as an energy crop, being utilized for the production of bioethanol. Similar to corn-based ethanol, cassava-based ethanol can be blended with gasoline; the product is named as gasohol and used as an alternative fuel in automobiles. The promise of cassava as potential feedstock for bioethanol production in Thailand has raised a critical concern for food security. To sustain a cassava-based bioethanol industry, it is important to improve cassava-ethanol production

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technology as well as to increase cassava root productivity. The development of cassava-bioethanol production technology aims for a process with high-yield (litre of ethanol per kg of cassava feedstock), energy and water saving, as well as near-zero discharge to ensure that all biomass residues are completely exploited with minimal resource consumption [1]. Yields or root productivity of cassava roots vary significantly with varieties and growing conditions. Higher root yields can be obtained by well-managed farm practices including time of planting (early in the wet season), land preparation (plowing by hand or mechanically and ridging), preparation of planting materials (age of parent plants, storage of stems, length and angle of cuttings, chemical treatment), planting method (position, depth of planting and spacing), fertilization (type of fertilizers-chemical vs. organic, dosage, time and method of fertilizer application), erosion control, weed control, irrigation and intercropping [2, 3].

The most serious pests of cassava include mites, hornworms, whiteflies, mealybugs, lace bugs and stemborers. Mealybug attacks in Thailand resulted in yield losses estimated as high as 25% in 2009/2010 [4]. To minimize the use of chemical pesticides, biological control can be applied for pest management. The fungus *Beauveria bassiana* is a broad-spectrum insect pest that can be utilized in insect pest control. Although it can infect and kill many insect pests, its efficiency (assessed as a percentage of insect death after inoculation by the fungus) can vary greatly (approx. 20-100%). The fungus *B. bassiana* has been used to control the destructive mealybugs in cassava fields in Thailand. The field trial results indicated that a spray of *B. bassiana* spores along with water-drip irrigation could decrease the mealybug population by up to 75% compared with a no-spray, no-irrigation control. This decrease in mealybug population was prominent particularly in the dry season or in a no- or low-rainfall period during the rainy season. The use of this biological control fungus could increase a population of natural enemies of mealybugs such as lacewing, ladybug, or spider in *Beauveria*-treated plants compared with pesticide-sprayed plants. Better understanding of insect pathogenesis mechanisms by the fungus on insects will be fundamental for improvement of its efficiency in field use.

The highest root productivity has been reported in India (i.e. 40 tons/hectare) for a small plot of planting area which is irrigated rather than rainfed. In Thailand, the national average yield of cassava root is approximately 20-25 tons/hectare. Instead of relying only on rainfall, irrigation by water dripping is now

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being introduced. It is expected that the national average of cassava root productivity planted with good farm management and selected varieties can be doubled, i.e. from 25 to 50 tons/hectare [5]. In addition, the advances in molecular biology and genetic engineering provides the possibility to develop varieties with improved traits, e.g. high starch yield, specific starch properties, disease and pest resistance, well-adapted to climate change and poor growth conditions. By combining good farming practice with varietal improvement, the root productivity can be potentially improved to more than 50 tons/hectare.

Zero-discharge process for cassava production

The starch processing technology of Thai cassava industry has been developed from simple extraction and drying processes to modern, fully automated controlling processes. Currently, most cassava starch factories in Thailand are in the transitional stage to become multi-product producers using a zero-discharge process (Figure 4). By implementing the zero-discharge concept (3R - Reduce, Recycle, Replenish), the process of most starch factories now consume less energy (by employing highly efficient equipment), less water (by using recycled water, typically from the separator to root washer), less chemicals (by good handling of raw materials) and less roots (by increasing starch extraction efficiency of machinery). More importantly, the replenishment of biogas obtained from the anaerobic treatment of wastewater instead of petroleum-based energy has remarkably been recognized as another significant development in the progress of the industry. Currently, more than 90% of the total cassava starch factories in Thailand have installed and utilized anaerobic wastewater treatment systems to produce biogas which can cover 100% of the factory's thermal energy requirements. Additional biogas is converted to electricity for use in the factory and/or selling back to the grid. The solid waste after starch extraction, i.e. cassava pulp, is also used for biogas production and animal feed in a form of dry tapioca fibre. The development of cassava pulp to other value-added products is also showing continual progress.

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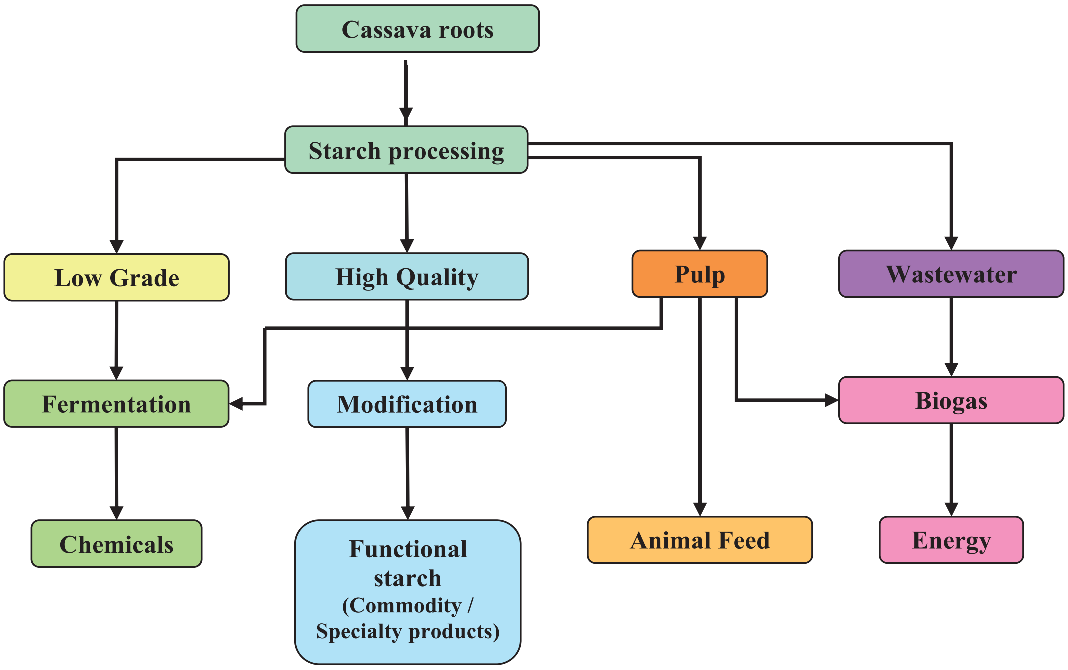

Figure 3. Structure of modern cassava starch factory with multiple products and (near) zero-discharge process.

Cassava-based products for better living

Health products

Currently, starch, in both native and modified form, has played a major role in the food industry in order to improve product attributes and shelf life stability. The application of starch in food products is now extended to improvement of nutrition and health benefits. As a consequence of more knowledge on starch structure and properties, starch is tailored-made to have specific functionality. Both granular (e.g. size, crystalline, amorphous, pore, surface charge) and sub-granular (e.g. molecular weight, conformation, branching structure, functional groups) structure level of starches can be modified through physical, chemical and enzymatic processes which introduce changes in phase transition, rheological properties and enzyme hydrolysis. This leads to the development of food products with more nutrition benefits such as low or non-caloric, high dietary fibre, slow digestion, low glycemic index (GI) and prebiotic. In addition to function as carriers, disintegrants and control release agents in tablet production, starch can have a major role in the diet of patients or elderly who need to control food nutrition without subsequent loss of appetite.

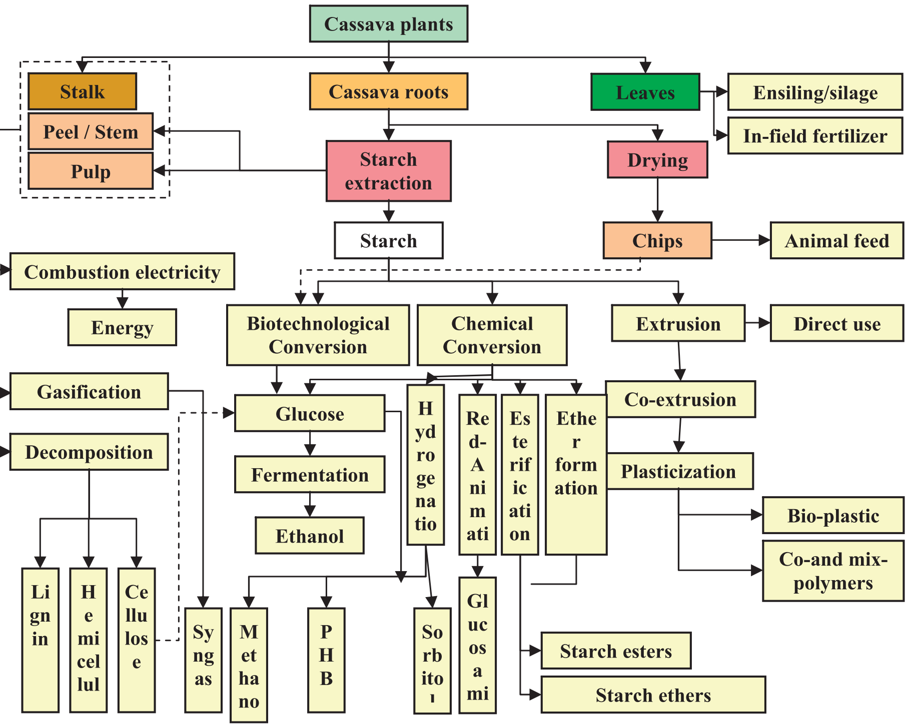

Figure 4. Effective use of cassava crop in a biorefinery.

Cassava-based biomaterials

With a rising concern for environmental impact, finding alternatives to substitute petrochemical products has gained much attention throughout the world. Instead of exploiting oil/petroleum-based materials, attempts have been made to develop the use of sustainable and renewable resources by bioprocess. These bio-products have high potential for future growth in various applications including films, packaging, fibres, adhesives and super-absorbents according to their biodegradability attributes. When used as biomaterials, starch can be used in two major forms, i.e. as monomer and polymer. A glucose monomer obtained from starch hydrolysis, preferably by enzyme process, is a good substrate for microbial fermentation. A spectrum of fermented products can be generated depending on microbial types. Some significant ones are lactic acid for making polylactic acid (PLA), succinic acid for making polybutylene succinate, propanediol and polyhydroxybutyrate (PHB). When used in polymer form, starch can be used in the form of granular or gelatinized starch. The major advantage of using starch is low cost, high quantity, renewable and biodegradable. However, starch is more hydrophilic and has less mechanical properties than conventional petroleum-

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based materials. These inferior properties can be diminished by starch modification and composite blends with other materials. Table 1. shows some of the starch-based biomaterials and related technology.

Table 1. Starch-based biomaterials and their related technology and relevant application.

Physical characteristics	Related fabrication technology	Relevant application
Film / Multilayered film	Tubular blow film extrusion	Packaging
	Film casting	Agricultural product
	Spin coating	Electronic device
	Sheet extrusion	Circuit board
Woven fibers / Web	Dry spinning	Geotextile
	Melt spinning	Packaging
	Spunbond	Agricultural product
	Melt blowning	Clothing
	Flash spinning	Carpeting
Non-woven fibers	Electrospinning	Tissue scaffold
	Spunbond	Filtration
	Melt blowning	Drug delivery
		Wound dressing
Fluid / Colloidal	Extrusion	Bioadhesives
		Fillers
Porous structure	Injection molding	Absorbent
	Extrusion	Tissue scaffold
	Foaming extrusion	Pigment base
	Solvent casting and particle leaching technique	Loose fill
Molded articles	Extrusion blow molding	Container
	Injection blow molding	Bottle
	Stretch blow molding	Tay
	Compression molding	Electronic device
	Transfer molding	Automotive parts
	Thermoforming	

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Conclusion

In Thailand, cassava has been demonstrated to be a viable cash crop for millions of farmers as well as an industrial crop that establishes a great value chain. Accordingly, the crop has played a significant role in the socio-economic development of the country. The prominence enjoyed by cassava in Thailand has been realized by all stakeholders, including government, academic and private sector, who have worked collaboratively to strengthen the industry's competency. The industry continues to develop and improve its capability to effectively utilize the crop, not only the roots but also other biomass, which has lead to the promising future of cassava-based biorefineries.

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