AGRICULTURE SCIENCE JOURNAL

Cassava – silently, the tuber fills[1] ...

The lowly cassava, regarded as a poor man's crop, may help save the world from the curse of plastic pollution.

By S.L. Tan

Tuberous roots, stems and leaves

Cassava is an ancient crop of the American tropics. By 1492, when Columbus arrived in the Americas, it had already spread in cultivation all over the American tropics and subtropics. The Portuguese introduced it to Africa but it took a long time to arrive in Asia. It was first recorded in Sri Lanka in 1786. It arrived in India via the Botanic Gardens of Calcutta in 1794. In Asia, it has been regarded as a poor man's food crop, and has long been neglected in research agendas. As an industrial material, it has great potential for commercial production and processing. Much can still be done to develop new applications. The only limiting factor is our imagination!

Cassava (*Manihot esculenta*), also known as tapioca belongs to the Family Euphorbiaceae, and have as its cousins such important economic species as the rubber (*Hevea brasiliensis*) and castor bean (*Ricinus communis*).

Of the top staples in the world, cassava ranks fifth in terms of production and sixth in area cultivated. In Malaysia, while it is the most important root crop, cassava covers only an area of 3,053 ha, followed by sweetpotato. This minor crop status has not always been the case. In its heyday in the mid-1970s, cassava cultivation peaked at 22,500 ha.

[1] From the Malay proverb: *Diam-diam ubi berisi, diam-diam besi berkarat*—Silently the tuber fills, silently iron rusts.

Ranking of top staple crops in the world (2013)

Crop	Production Rank	Production (tonnes)	Area Rank	Area (ha)
Maize* (*Zea mays*)	1st	1,016,736,092	2nd	184,192,053
Rice (*Oryza sativa*)	2nd	745,709,788	3rd	164,721,663
Wheat (*Triticum aestivum*)	3rd	713,182,914	1st	218,460,701
Potato (*Solanum tuberosum*)	4th	368,096,362	7th	19,463,041
Cassava (*Manihot esculenta*)	5th	276,721,584	6th	20,732,193
Soybean (*Glycine max*)	6th	276,406,003	4th	111,269,782
Sweetpotato (*Ipomoea batatas*)	7th	110,746,162	8th	8,240,969
Sorghum (*Sorghum bicolor*)	8th	61,384,559	5th	42,120,446
Yams (*Dioscorea species*)	9th	60,196,312	10th	5,053,272
Plantains (*Musa species*)**	10th	37,162,205	9th	5,407,361

* Used also as a major feed grain and for biofuel production ** Only 2012 data available Source: FAOSTAT (2014)

Cultivated areas of cassava, sweetpotato and cocoyam in Malaysia (2012)

Root crop	Area (ha)
Cassava	3,053
Sweetpotato	2,386
Cocoyam	384

Botany

Although it grows to become a small tree or shrub and qualifies as a semi-perennial plant, cassava is grown as an annual and is typically harvested after 8–10 months for food, or after 12 months for starch. Due to its rather long cropping season, this plant is most widespread near the equator between the latitudes of 15°N and 15°S. The most favourable growing conditions are humid warm climates with temperatures between 25 and 29°C, and an annual precipitation of 1000–1500 mm, ideally of even distribution.

Cassava is widely adaptable. It will grow on a range of soils and rainfall regimes, but it grows best on sandy loam soil of medium to high fertility and good drainage. Otherwise, it will fail to reach its full yield potential.

While cassava produces sexual seed, in practice it is propagated vegetatively using mature stem cuttings. Cassava varieties or cultivars are therefore actually clones, and non-sexual propagation preserves the integrity of a genotype. Planting sexual seed would result in seedling populations of diverse genotypes; thus seeds are only used in breeding and selection for new varieties.

Cassava germplasm is usually maintained as living field collections. Cassava has a great range of genetic variability as shown by countless combinations of leaf, stem and root traits—in terms of shape, colour and other morphological, physiological and agronomic traits. The International Center for Tropical Agriculture (CIAT) in Colombia has a depository of 6,592 accessions from 28 countries, representing

Farmer and young cassava crop

The economic part of the crop is the storage roots, formed by starch deposition in the adventitious roots. Having the economic part of the plant growing underground has several advantages for the farmer. The storage roots act as a food reservoir in times of famine, and indeed it has been suggested that root crops may be the only thing left to eat in the aftermath of an atomic war. Also, unlike crops which bear their produce above the ground, a root crop like cassava can have a much higher harvest index[2] as it does not have structural restrictions to counter the development of a large economic part.

5,709 clones of *M. esculenta* and 883 genotypes of wild *Manihot* species. In addition to a field collection, this germplasm is also conserved using in vitro techniques.

Tuberous roots

Bitter and sweet cassava

All tissues in cassava contain cyanogen, which is released as hydrogen cyanide when linamarase, an enzyme residing in the cell, is activated when the cells are ruptured. Based on the cyanogen content in the pith of the storage root, cassava varieties

[2] Harvest index is defined as the ratio of the weight of the economic plant part to the total weight of the plant (including that economic part).

are loosely classified as "bitter" and "sweet" varieties. Varieties with roots which are higher in starch are usually "bitter".

While the roots of the "sweet" or edible varieties are safe to eat, this does not mean that the shoots of the same are also safe. Indeed, cassava leaves and shoots often contain more than four times the amount of cyanogen found in the roots.

Cassava has long been maligned for impoverishing the soil

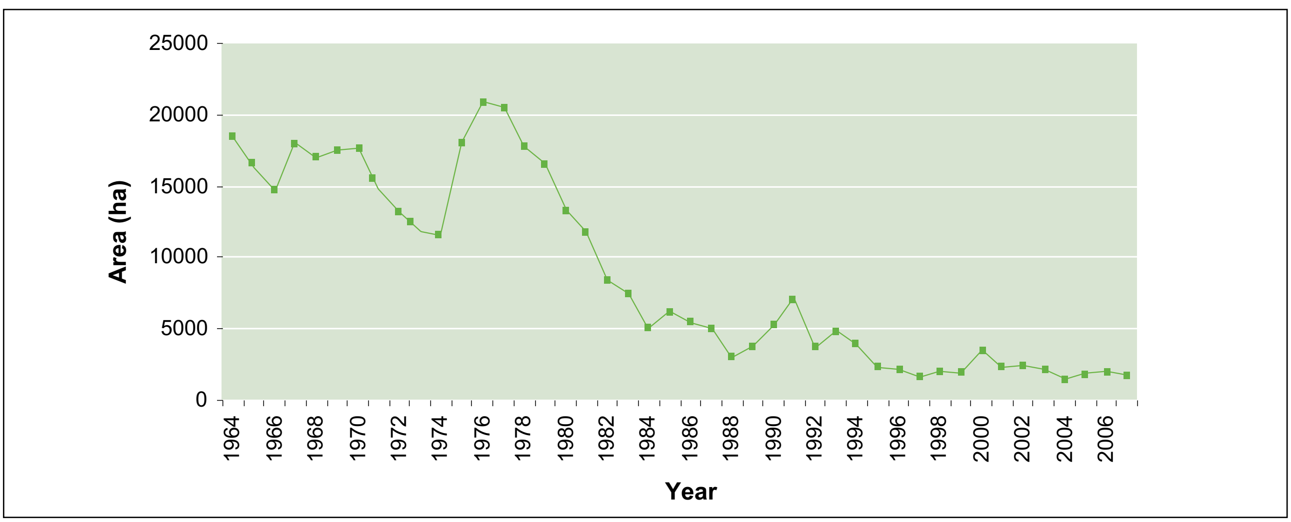
Indeed, it used to be a condition in leases for agricultural land in Peninsular Malaysia that the land should not be planted with cassava! This probably came about because this crop was a popular choice in the practice of shifting agriculture which involves *"tanam, tinggal, tuai"* (plant, leave, harvest). The reasons cassava features prominently in shifting cultivation are: (i) it is easy to grow (with little maintenance required), and (ii) it can be grown without fertilizer because of its efficiency in extracting nutrients from the soil.

Of course, repeated planting without fertilizer is not possible. Indeed, which crop can grow without fertilizer? The table below shows that at a high root yield of 35.7 t/ha, cassava does not remove more nitrogen and phosphorus than many of the other crops, but does extract more potassium. When cassava yield is lower (e.g. 11 t/ha), N, P and K removal is even less. Potassium is essential for root bulking and starch deposition in cassava roots.

Removal of nitrogen (N), phosphorus (P) and potassium (K) in kg/ha by cassava and selected annual crops

Crop	N	P	K
Cassava/fresh roots*	55	13.2	112
Sweetpotato/fresh roots	61	13.3	97
Maize/dry grain	96	17.4	26
Rice/dry grain	60	7.5	13
Soybean/dry grain	60	15.3	67
Groundnut/dry pod	105	6.5	35
Sugarcane/fresh cane	43	20.2	96
Tobacco/dry leaves	52	6.1	105

Area of cultivation with cassava, Peninsular Malaysia (1964-2007)



It is entirely possible to maintain cassava in permanent cultivation on the same piece of land if an adequate and correct balance of NPK fertilizer is supplied at each new season of cropping

In Thailand, some areas have been under cassava cultivation continuously for the past 40 years or so.

In Malaysia, cassava has fewer pest and disease problems than in its centre of origin in South America. There is no 'frog's skin disease' which plagues cassava in the Americas, and also no 'African cassava mosaic virus' which devastates the crop in Africa. The common diseases in Malaysia are the leaf spots caused by the fungi *Cercospora henningsii* and *C. caribaea,* and bacterial blight (caused by *Xanthomonas axonopodis pv. manihotis,* but much milder than the destructive form encountered in South America). The leaf spots which appear on the older less photosynthetically-active leaves do not have much of a detrimental effect on cassava yield. Occasionally, white root disease of rubber (caused by *Rigidoporus lignosus*) occurs if cassava is planted after rubber. This can be managed by field sanitation, i.e. removal of infected old wood in the soil.

The importance of adhering strictly to quarantine regulations when importing planting material of cassava can be appreciated from the unpleasant lesson learnt by Thailand when the pink mealy bug (*Phenacocus manihoti*) was accidentally introduced from Africa. This pest quickly spread and caused yield losses valued at 18,704 million bahts in the two years, 2010–2011. The Thais had to resort to biological control using a parasitic wasp to overcome the problem.

Cassava/tapioca crisps and crackers

Starch and sago pearls

Cassava today and tomorrow

Food and food products

Traditionally, cassava is used as a food staple by those who cannot afford the more expensive but favoured cereals, such as rice. However, in Malaysia, cassava is eaten as a supplementary food — either steamed, boiled or fried in batter (fritters), or for making *bingka*, (a traditional Malay cake), *tapai* (fermented cassava) and *bubur caca* (a sweet dessert soup). There are also small cottage industries making traditional snacks, e.g. *kerepek* (crisps), *keropok* (crackers) and *opak*. All these forms of usage have a rather limited market when in fact there are far greater prospects in utilization.

Dried chips, a feedstuff

Starch

The production of cassava starch is a well-established industry, but has dwindled drastically from the early 1970's to almost nothing today. To keep a small starch factory in operation throughout the year, up to 2,000 ha of cassava has to be planted. Such a large tract of almost flat land is no longer available to cassava because there are far more lucrative crop choices.

Starch has myriad uses, both for food and non-food applications (see Table). One peculiar but desirable characteristic of cassava starch is its propensity to puff, making it particularly useful in extruded snacks and in batters for frying as it gives a crispy/crunchy texture to the product.

Feedstuff

The livestock industries in Malaysia, particularly the non-ruminant subsectors, are heavily dependent on imported feedstuffs of which grain maize alone amounted to 3.4 million tonnes (valued at RM2.267 billion) in imports in 2013. Cassava being rich in carbohydrate is a good source of energy in livestock feeds.

Grain maize, the gold standard for energy-rich feedstuffs, can be replaced

Uses of starch

Food applications	Non-food applications
1. Thickening agent in: • Puddings • Pies • Soups • Sauces • Jellies	1. Textile industries – sizing, strengthening and finishing
2. Baby and convalescent foods	2. Paper industries, including cardboard – sizing and bonding
3. Confectioneries: • Moulding of cast candies • Biscuits	3. Dusting agent, e.g • rubber gloves • condoms
4. Bodying agent (e.g. caramels)	4. Laundry
5. Monosodium glutamate (flavour enhancer)	5. Plywood – adhesive and veneer
6. Sweeteners: • Glucose • High fructose syrup • High fructose glucose syrup	6. Gums and glues (including rewettable glues in postage stamps, envelopes)
7. Modified starches, e.g. • Sorbitol (humectant, preservative) • Dextrin • Ascorbic acid • Precooked soluble starches, e.g. "instant" tapioca puddings • Thin-boiling starches (for candy manufacture) • Oxidized starches	7. Chemical industries, e.g. • Lactic acid • Acetic acid/vinegar • Acetone • Ethanol • Butanol
8. Encapsulation: • Flavours, fats/oils, vitamins • Non-gelatin capsules	8. Oil-well drilling
9. Fat replacer	9. Superabsorbent gels – e.g. in disposable diapers and sanitary napkins

Store full of chips

up to 30% by cassava in non-ruminant feeds, namely pig and poultry rations. Being deficient in certain essential amino acids, the addition of 0.1–0.2% methionine to cassava can push the substitution level further to 50–60%.

There is ample scope for replacing at least partially the imported grain by local production of cassava. Indeed, Thailand has built up a million-dollar industry growing cassava for export as dried chips and pellets, mainly to Europe. The poor protein profile of cassava can be improved by single-cell protein technology using yeasts and fungi such as *Rhizopus*, *Aspergillus* and *Neurospora*. It has been reported that the resulting materials have crude protein content of around 12% (8% true protein), but are still low in methionine and lysine which need to be supplemented. More recently, *Schwanniomyces castellii* and *Cephalosporium eichhorniae* have been used.

Net energy ratios and greenhouse gas emission for selected materials used in bio-fuel production

Material	Net energy ratio	Greenhouse gas emission	
		kg/L	Reduction
Sugarcane	8.3	1.08	56%
Sugarcane (data from Thailand)	9.3–10	n/a	n/a
Sugarbeet	1.9	n/a	35–56%
Corn	1.35–1.5	1.94	22%
Corn (data from Thailand)	4–5.2	n/a	n/a
Cassava (data from Thailand)	8–9.1	0.84	63%
Cellulose from corn stover	4.39	n/a	n/a
Cellulose from switchgrass	8.3	n/a	n/a
Cellulosic ethanol	2–36	0.23	91%
Bio-diesel (from canola)	2.5	0.91	68%
Bio-diesel (from soybean)	2.5–3.0	n/a	41%
Bio-diesel (from palm oil)	6.0–9.5	n/a	>70%
Petrol	1.0	2.44	0%
Diesel	1.0	2.80	0%

Biodegradable plastic bag

Bio-fuel

Various crops have been tried for producing bio-diesel and fuel alcohol, among which are oil palm (in Malaysia) and rapeseed (in Europe) for bio-diesel, and sugarcane (in Brazil), corn (in USA) and cassava (Thailand, China) for ethanol. Currently, available data shows that sugarcane produces most fuel alcohol per hectare of land, followed by sweet sorghum, while sugar beet and cassava are at par with one another.

It is also relevant to look at the net conversion ratio or NCR (defined as the number of units of energy produced from each unit of energy consumed in producing that energy) as well as the capacity for reducing greenhouse gas emission by the respective crops used in bio-fuel production. NCR is highest for sugarcane at 8.3 while corn is a dismal 1.35–1.5. Data from Thailand show higher NCR for sugarcane and corn because less high-energy inputs are used in their production unlike in Brazil or the USA. What is interesting is that the NCR for cassava has been reported at 8–9.1

Biodegradable plastics

Over 200 million tonnes of plastic are manufactured annually which include about 500 billion plastic bags being used worldwide. It has been estimated that our planet and its wildlife and marine fauna are facing more than 100 million tons of plastic pollution per annum. This is mainly because of the ”throw-away”, “one-time-use” attitude of many people these days, worsened by the fact that plastics take 300 years to photo-degrade.

To arrest the relentless march of this monster we have created, a number of countries have begun to ban the use of plastic bags. Germany leads in the fight against plastic pollution. As early as 1991, a Packaging Ordinance was passed which shifted to industry the responsibility of managing packaging until the end of its life cycle, including the cost of recycling after the consumers discard the packaging. This led to some companies taking action not only to reduce the weight of packaging, but also to switch to materials which are more cheaply and easily recycled, e.g. from plastic packaging to paper. However, according to BASF, it is more expensive to recycle plastics than to manufacture new plastics. Thus, interest in biodegradable plastics was born, which will hopefully “wean” us from our overdependence or addiction to plastics.

Biodegradable food packaging

"Biodegradable" means being able to be broken down into simpler substances by the activities of living organisms, and so will not persist in the environment. Traditional plastics are not biodegradable because of their long polymer molecules which are too large and too tightly bonded together to be decomposed by microorganisms. However, biodegradable plastics which are based on natural plant polymers derived from starch have molecules that are readily decomposed.

Starch itself is made up of a combination of amylose and amylopectin molecules. All biodegradable plastics made from starch start from the basic material polylactic acid or polylactide (PLA). Starch is first transformed to lactic acid by bacterial fermentation, and then chemically treated to link the molecules together into long chains or polymers, thus producing PLA.

The commercialization potential of biodegradable plastics is attested by the success of an Indonesian company Tirta Marta. Its product Ecoplas®, made from cassava starch, is 100% bio-degradable and renewable. Ecoplas® has captured not only 90% of the shopping bags used by branded stores and supermarkets in Indonesia, but also penetrated a dozen other countries, including USA.

The challenge to innovators is to look into more diverse applications of cassava which will benefit our health and well-being, as well as to create new sources of wealth. A few possible lines of investigation include the following:

The World uses 500 billion plastic bags and generates 100 million tons of plastic pollution every year.

Specialty foods

Coeliac disease is an allergic reaction to gluten, a protein found in wheat, and to similar proteins in rye, barley and oats. These proteins damage the villi lining the small intestine which play a significant role in digestion. When damaged and inflamed, the villi are unable to absorb food properly, often resulting in diarrhoea and malnutrition. More seriously, infertility, osteoporosis and bowel cancer are possible long-term consequences. It is believed that coeliac disease develops as a result of feeding foods containing gluten to an infant younger than four months.

One in 133 people, or more than two million people in USA, have the disease, while in the United Kingdom the incidence is one in 100 people. In Italy, the prevalence is one in 250. Men and women appear to be affected equally. Among those people who have a first-degree relative—a parent, sibling, or child—diagnosed with coeliac disease, the incidence can rise to as high as one in 22 people.

Being allergic to wheat gluten means many common food products such as most bakery products and pasta made from wheat flour are taboo to those suffering from coeliac disease. This opens up opportunities for developing food products from non-gluten flours, such as cassava flour, targeted specifically for this niche market. For example, various gluten-free formulations have been advocated using cassava flour together with rice, corn and soy flours to make bread. Many more food products can be developed.

While cassava is typically not high in carotenoids, CIAT (the International Center for Tropical Agriculture) is currently developing high carotene cassava to enhance its nutritive value to benefit the many in the world who depend on this root crop as a staple.

Cosmetics

There has been a scare over a link between ovarian cancer and the use of talcum powder. It is believed that talc, which is a mineral processed from mined talc rocks, contains minute fibres very similar to those of asbestos, an established

Granule size of selected crop starches compared to particle size of talcum powders

Starch source	Granule size (µm)		Granule shape
	Reference A	Reference B	
Root starches:			
Cassava	3–34	3–28	Mix of round and truncated
Sweetpotato	12.3–21.5	4–40	Mix of round and truncated
Potato	10–75	10–70	Oval
Cereal starches:			
Rice	3–8	2–13	Polygonal
Wheat	5–45	3–34	Round
Corn	16–18	5–25	Truncated, polygonal
Talcums:			
Baby powder	Particle size	8–10	
Body powder	Particle size	37–74*	

Reference A: Tothill, I.E. (2003) Rapid and on-line instrumentation for food quality assurance, p. 314. Woodhead Publishing, 406 p.
Reference B: http://www.corn.org/methods/B-25.pdf

*US Standard for body powder

carcinogen. Indeed, cosmetic grade talc, without any asbestos-like fibres, has caused tumours in test animals (Cancer Prevention Coalition, University of Illinois at Chicago, USA. url: http://www.preventcancer.com/consumers/cosmetics/talc.htm).

Typically, the particle size for talcum powder ranges from 8-10 µm for baby powder and 37-74 µm or finer for body powder. Rice starch used to be popular as *bedak sejuk*, a face powder, among the Malay and *nyonya* communities; thus, replacing mineral talc with crop starches in making cosmetic powders is nothing new. It is also interesting to note that cassava starch has granule sizes which fall within the particle sizes in talcum powder. Hence, there is potential for cassava starch to be used in the manufacture of talc-free baby and perfumed body powders – to assuage the fears of cancer-causing effects from long-term use of talcum powders. Indeed, this is already happening: AGRANA Stärke GmbH is using starches in cosmetic products such as creams and lotions (e.g. sun care products, face creams), powders (baby, foot and body powders, powders for decorative cosmetics), and dry hair shampoos. It has been found that starch particles can reduce greasiness of creams like sun creams, and absorb oil and moisture, giving a smooth feel.

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