Reappraisal of Edible Canna as a High-Value Starch Crop in Vietnam

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Edible canna (Canna edulis Ker-Gawler) or Queensland arrowroot is a vegetatively propagated root crop from the Andes. Abundant archaeological canna remains found in the Pacific littoral in Ecuador and Peru predate most other food crops in this area (Piperno and Pearsall, 1998). That suggests canna was a fairly common staple in prehistoric times, but was successively diminished by the introduction of other crops, notably by maize from meso-America and by Old World crops in the wake of the Spanish conquest. In the Andean highlands, canna continues to be grown as a subsistence crop or, to a lesser extent, as a cash crop for occasional ritual use. However, it is of no economic significance and is largely unknown in its native range.

Production advantages of canna include high N-use efficiency, high yields and harvest indices (Hermann et al., 1997), shading tolerance, outstanding drought tolerance and water-use efficiency (Jureit, 1997), and the absence of pest and disease and replant problems. A severe constraint to its wider use is its long duration to full productivity.

Similar in texture and taste to sweetpotato (Ipomoea batatas), the starchy canna rhizome is actually a palatable food, but it has an unattractive brown color and is rather fibrous. More important, canna must be boiled or steamed for several hours to soften root tissue sufficiently for it to be consumed. That constrains its use not only in urban areas but also in poor, rural highland communities where fuel wood is scarce. Thus, there is little scope for canna to regain some of its previous importance as a food for direct consumption.

Yet the ease with which canna starch can be extracted using makeshift equipment has not escaped the attention of rural people in the search for wheat flour substitutes. Canna has the largest starch granules known. They quickly settle out of a suspension of grated rhizome tissue. In the northern Andes, cottage industries have sprung up to extract canna starch, albeit of questionable hygiene and low productivity. Although the starch is highly valued locally, it is limited to certain bakery products to which it confers a spongy and light texture not achieved with alternative raw materials (Hermann, 1994).

Canna production in the Andes is dwarfed by the crop’s use in tropical Asia, particularly in Vietnam and China. It spread there in past centuries presumably because of the ornamental value of its flowers. Because of its highly localized importance, and generally restricted role as pig feed and famine food, its presence in backyard gardens has rarely been noted. In recent decades, however, canna starch production in Vietnam, almost exclusively for transparent noodles, has become a major agricultural operation. This paper examines the principal features of canna use in Vietnam based on rapid appraisals in 1992 and 1995, and research from 1996 to 1998. The information provided fills a gap in the agricultural and food science literature, and identifies priorities for further research and breeding efforts.

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**Canna production**

Elderly rural informants invariably state that the use of canna as pig feed has a long tradition in Vietnam. In the 1950s and 1960s, when rice harvests were as low as 2 t/ha, canna rhizomes also entered the human diet to a considerable degree. In some areas, canna was produced to a much larger extent than today. At the time, some starch was extracted and used rather unspecifically as a thickener. Beginning in the late 1960s and early 1970s, the principal use of canna starch for the manufacture of cellophane noodles emerged and has since fueled the expansion of canna production.

Canna is grown in all mountainous provinces and also in some low-lying areas. According to official estimates, some 20,000 ha of canna are cropped in northern Vietnam. In the five leading canna-producing districts of Tanh Hoa Province (Red River Delta) alone, 2,930 ha were registered in 1998. Recent evidence suggests that from 4,000 to 5,000 ha are grown in the South, principally in the provinces of Dong Nai, Song Be, Tay Ninh, Gia Lai, and Lam Dong. Other roots and tubers used for starch in Vietnam include cassava (*Manihot esculenta*) for a range of secondary processed products such as maltose and fermentation products, and kudzu (*Pueraria lobata*), a tuberous legume yielding a highly prized starch used in a traditional soft drink.

In northern Vietnam, canna is cropped principally in the highlands (300-1,200 m) of Hoa Binh and Son La provinces, which border Laos and China, and in the Red River Delta at sea level. Cropping is strictly seasonal, beginning at the onset of rains and lasting for 10-12 mo. Propagation is by apical rhizome sections that are either immediately replanted or stored for 2-3 mo to allow for staggered harvesting.

In the rice-dominated cropping systems of the Red River Delta, canna is mostly relegated to the least fertile and unirrigated uplands such as river dams, backyards, and other areas that do not compete with food production. Occasionally, canna is grown on more fertile land after a winter vegetable crop. Under high N fertilization, yields can exceed 80 t/ha in 8-9 mo. Usually, however, yields are under 40 t/ha and reflect marginal inputs.

In the highlands, most canna comes from agroforestry systems or shifting cultivation. In agroforestry systems, which may involve steep slopes, shading can exceed 50% and the crop is not fertilized. No plowing is practiced. Production is therefore extensive with no external inputs and low yields.

In Vietnam, as in other parts of Asia, edible canna shows little variability and belongs to a broad-leaved morphotype. Fully expanded leaves assume a near-horizontal orientation as opposed to the erect leaf habit of most Andean cultivars. Another special feature of Asian starch canna is its hypogaeic rhizome compared with the more common rhizome position at or above the soil surface in Andean material. Vietnamese canna is reported by farmers to be seed-sterile, and indeed we never found sexual seed in mature fields. All six accessions examined were found to be triploid (2n = 27), which suggests they originated in the northern Andes, where such material is common. That is corroborated by randomly amplified polymorphic DNA analysis, which places Vietnamese canna next to triploid Colombian cultivars (Hermann, 1999).

**Starch extraction**

Some canna starch is extracted in the highlands, but the bulk of the harvest is trucked to processing villages in the Red River Delta about 100-200 km away. Processing of the rhizomes into starch and then into noodles takes place in a number of highly specialized villages. Many of them add domestic rhizomes to those imported from the highlands. Some villages specialize in starch extraction, others in noodle making, and still others provide processing equipment such as drying racks, baskets,
graters, and noodle cutters. Several of these functions may even coexist in a given village.

The economics of canna production and processing are little understood, but production in the lowlands, i.e., near the processing sites, and noodle-making seem to be particularly profitable. Farmgate prices for canna between 1990 and 1995 were slightly higher than for cassava and double that of sweetpotato, although cassava and sweetpotato have much higher dry matter (DM) contents. Canna rhizome, starch, and noodle prices fluctuate seasonally suggesting corresponding profit variation.

Starch processors require the rhizomes to be free from the adventitious roots that firmly anchor the canna rhizome in the soil and remain attached to it after harvest. The soil and small stones they trap can damage grater surfaces. Up to 20 person hr are needed to remove the roots from 1 t of canna rhizomes.

Vietnamese starch processors use mostly engine-driven drum graters. They are locally made and consist of a hardwood cylinder, 20-25 cm diam and 30-40 cm long, with longitudinal rows of nails providing an abrasive surface. Only wealthier households own such graters and rent them out to other processors, moving grater and engine around on wheelbarrows. Figure 1 provides a schematic of a typical, family-owned rural starch factory. The pulp generated by the grater is collected in buckets and poured onto a cloth suspended (immersed) in stationary water tanks. The pulp is then moved across the cloth and kneaded to release the starch (Figure 2), which settles to the bottom of the tank. The

![Figure 1. Schematic of canna starch factory in Moc Chau, Vietnam.](image-url)
remaining fiber may be passed on to workers at another tank (Figure 1) who repeat this process to extract additional starch and the fiber is finally discharged.

The starch sediment accumulating in the rectangular tanks is shovelled into circular washing tanks and is given a number of washes by stirring it in clean water. After each wash, the starch is allowed to settle for an hour or so and a lighter, brown slurry on top of the firm starch cake is scraped off. Once supernatant water of the final washing is siphoned off, any free water remaining on the starch sediment is soaked up with hygroscopic materials. Bags filled with ash, or bricks that have been dried over a heat source and then cooled, are commonly used. The final water content of the starch as it comes out of the sedimentation tank is 46.5-49.0% (wet wt basis).

The farmer-extracted starch in Vietnam ranges from between 10 and 15% of fresh rhizome weight (Table 1), with three out of four observations being between 10 and 11%. That is roughly equivalent to half of rhizome DM. Actual starch yields are about three-fourths of total extractable starch, which includes starch released from process residue by treatment in a food blender. Extraction efficiency across production zones is thus much better than in other tuber crops (having smaller granules with lower sedimentation rates) but there is room for improvement.

Noteworthy are the high concentrations of soluble solids (shown to be sugars by Ripperton, 1927), as revealed by the high refractometric index. This indicates that wastewater must have high values of biological oxygen demand and illustrates its polluting potential. Table 1 does not suggest differences between Vietnam and the Andes in canna DM content, extraction efficiency, or total extractable starch, but no firm conclusions can be drawn from these preliminary data.

Traditionally, all starch has been dried in the open. Otherwise it quickly deteriorates

Figure 2. Rural women workers washing canna pulp in Moc Chau starch factory, Son La province, northern Vietnam, 1995.
due to fermentation. Since the 1990s, however, most starch has been stored as wet starch until sale or further processing (which can be months ahead) by keeping it in anaerobic conditions. To that end, the starch cake is firmly pushed into polyethylene bags, containing an inner layer of foil and an outer layer of woven plastic. This practice obviates the need for large areas for starch drying and prevents airborne contamination. Table 2 gives retail prices for carbohydrate commodities on the Hanoi markets and shows the high relative value of canna starch.

In villages where hundreds of families engage in starch extraction, the disposal of residue and wastewater poses serious...
problems. Wastewater, which is rich in organic material, especially sugars, is discharged without treatment into streams and bad odors emanate from fermenting extraction residue.

Although extraction residue is used in various ways, its abundance makes it more of a liability than an asset. Some of the fiber-rich residue is returned to fields as mulch or is fed to pigs, either plain or mixed with rice bran. During peak processing, more residue is produced than can be consumed as feed and needs to be dried. It is spread out on all available surfaces in the villages, including walls and sidewalks. Larger processing units have also been known to ferment residue, a process that might add to its nutritional value. The light, brown slurry scraped off settled starch makes a good feed, especially if cooked with other components.

**Noodle making**

A small proportion of canna starch is destined for unspecific household uses or processed into minor products such as candies, cakes, and rice papers. Overwhelmingly, however, canna starch is processed into noodles.

Of the two techniques for making canna noodles in Vietnam, traditional extrusion is the older, but is practiced on a small scale. It involves forcing a freshly gelatinized and highly viscous starch paste through the perforations of a metal plate forming the bottom of an open-topped box. The noodles are directly released onto a drying rack. As with other extrusion noodles, they are round, but are unacceptably thick (1.8-2.0 mm diam) to most consumers. That is because of the large die diameter chosen to keep the extrusion force sufficiently low for manual operation.

Steam-sheeting, the technique used for well over 95% of canna noodle production, is apparently derived from rice noodle making for which a similar process is used. First, wet starch is slurried into a solution of fully gelatinized starch, which acts as a matrix keeping the starch granules in suspension and accounts for 5-10% of the starch in the resultant batter. This batter is then applied to a steam-heated textile membrane (Figure 3) and gelatinizes into translucent gel sheets. These are then transferred onto concave bamboo racks and are stretched by a factor of 2.5 into a rectangular shape (Figure 4). After preliminary drying to 55-58% moisture, the sheets assume a rubbery, nonsticky texture and

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**Table 2. Commodity retail prices for carbohydrate products, Hanoi, December 1995.**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Comments</th>
<th>Price (dong/kg)</th>
</tr>
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<tbody>
<tr>
<td>Canna noodles</td>
<td>From Huu Hoa</td>
<td>7500-8000</td>
</tr>
<tr>
<td>Canna starch</td>
<td>From Duong Lieu</td>
<td>7500</td>
</tr>
<tr>
<td>Rice noodles</td>
<td>From Huu Hoa</td>
<td>6000</td>
</tr>
<tr>
<td>Cassava starch</td>
<td>From Duong Lieu</td>
<td>3500</td>
</tr>
<tr>
<td>Cassava flour</td>
<td>‘From the mountains’</td>
<td>2500</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>From Australia</td>
<td>6000</td>
</tr>
<tr>
<td>Indica rice</td>
<td></td>
<td>4000</td>
</tr>
<tr>
<td>Japonica rice</td>
<td>Sticky rice</td>
<td>8000</td>
</tr>
<tr>
<td>White sugar</td>
<td></td>
<td>6500-6800</td>
</tr>
<tr>
<td>Brown sugar</td>
<td></td>
<td>5500</td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td>2500-4000</td>
</tr>
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US$1 = Dong 10,800.
can be easily handled for subsequent cutting into noodles. Two persons can produce 150 sheets/day or the equivalent of 160 kg of dry noodles (retail value US$110.00).

Typically, a guillotine is used to cut the noodles (Figure 5). It moves a stack of folded gel sheets incrementally toward a vertically moving knife that cuts off the noodles. This machine, originally developed for manual operation, has been semiautomated since 1993. A watchlike mechanism attached to the cutter and powered by an electric motor moves the gel stack and the cutting knife in a coordinated fashion. Automated cutting has greatly increased productivity but requires relatively high investment and thus has not completely replaced manual operation. The machine’s capacity is 400 kg of noodles/day per operator compared with 100 kg/day per operator with manual operation. Drying of the noodles to 18-21% final moisture takes place in a confined space (Figure 6).
Canna noodles belong to the class of cellophane or glass noodles with a glossy, transparent appearance. They are rectangular and are 0.8 mm thick. Bland and slippery, they add texture to a variety of Vietnamese dishes, especially to soups and stir-fried dishes. They are regarded as a luxury item and reserved for celebrations. Glass noodles are traditionally produced from mungbean (*Vigna radiata*) starch, which continues to be a superior raw material (Lii and Chang, 1981). However, Vietnamese canna noodles exhibit sufficiently high tensile strength to satisfy even demanding consumers. They stay firm and lose a minimum of solids during cooking. Being less wasteful and less costly to extract, canna starch has totally replaced mungbean starch as the raw material for glass noodle production.

Attempts to substitute canna starch with less costly sweetpotato starch have had mixed success because noodles made from pure sweetpotato starch are unacceptable to consumers. A proportion of 70% canna...
starch mixed with sweetpotato starch is deemed appropriate to retain the aspect and consistency of canna noodles (Lan and Huy, 1999).

**Discussion and Conclusions**

Declining direct consumption of canna in Vietnam and in the Andes is contrary to the occasionally stated view that canna is a promising staple for the poor in montane tropics. Future research and development should focus on canna as a source for starch with functional properties that make it a possible substitute for mungbean starch in glass noodle production, not only in Vietnam but also in other Asian countries. There is mounting evidence for canna starch also being functionally similar to potato starch in shared end products, high peak viscosity, high amyllose content, large granule size, crystallinity, and amount of covalently bound phosphorus (Hermann, 1994; Hulleman, 1995; Inatsu et al., 1983; Tu and Tscheuschner, 1981).

Canna and common commercial starches, however, are currently unequal competitors. For example, potato starch is being developed aggressively for a myriad of uses and novel products. In contrast, canna is scientifically neglected. Advanced technologies for its production and processing are unknown and the cultivars used have not been bred for specific uses.

The price competition from other starches, mainly from cassava and sweetpotato, will restrict canna starch use in the medium term to very specific applications. At current prices, it seems unlikely that new markets will open up for canna starch. Efforts should therefore be undertaken to reduce production costs. The Vietnamese retail price of dry canna starch was the equivalent of US$0.70/kg in December 1995. At that price, European high-grade potato starch may well be a threat to the Vietnamese canna starch industry. Opportunities for reducing production cost include:

- increasing extraction efficiency,
- increasing rhizome starch content and starch yield, and
- increasing labor productivity of starch extraction.

Current extraction efficiency ranges from 63 to 77% of total extractable starch. Improved grating surfaces are likely to succeed in releasing more starch from the fibrous rhizome tissue.

The increase of starch content will reduce shipping costs per unit DM and potentially increase starch yields. That will require varietal selection or breeding using Andean material, which is sexually fertile and has greater variability than Asian cultivars (Hermann et al., 1997). Breeding would also have to address the high residual sugar content, which exists at the expense of starch yields and incurs environmental costs as increased organic load in wastewater. Further research is also needed to identify germplasm with improved processing characteristics (extractable starch, oxidative browning).

Increased labor productivity, and probably higher starch quality, could be achieved by using rotary strainers to separate starch milk from fibrous residue. That would replace the onerous task of manual batchwise separation. Such intermediate technology could be produced domestically using blueprints from existing equipment. Stationary paddle washers, which were used to clean canna rhizomes earlier this century in Australia, could also help to reduce processing costs. Alternative technology includes rotating drum washers currently used in small cassava operations in South America. Such equipment would obviate the need for the very labor-intensive removal of adventitious roots.

Other than in wheat-derived pasta with its nonstarch components (especially gluten), the quality of starch noodles depends solely on the functional properties...
of the starch itself (Pagani, 1986). Hot canna gels have minimal adhesiveness and outstandingly high elasticity. That, in combination with the productivity of steam-sheeting, explains the wide adoption of this method in Vietnam and its apparent superiority over manual extrusion methods, which are so widely used in the manufacture of sweetpotato noodles in China. Also, hot canna gels are translucent. They do not need to be immersed in water or subjected to other cooling treatments following extrusion to produce the vitreous aspect and desired consistency required for other raw materials.

An assessment of the potential of edible canna, if conducted a few decades ago, would have concluded it was no more than an ethnobotanical curiosity, hardly worthy of promotion and conservation. However, canna use in Vietnam shows how product development can provide novel perspectives for the use of a seemingly obsolete crop. It demonstrates the unpredictability of future germplasm use and illustrates the need to conserve germplasm with no apparent value. Current use patterns of minor crops should not be taken for granted; they may well change over time.

References Cited