Diversification and Quality Optimization of Tropical Root Starches for the Global Food Starch Industry

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Abstract

The utilization of starch as a major food ingredient has considerable significance. Trade and export of food starches has contributed to the economic growth and viability of various developing countries. The global starch market however, is highly competitive, with industry consumers opting for high quality, but affordable and steady supplies.

Starch has multiple functions in food applications, most commonly as a bulking agent, binder, carrier, fat-replacer, for texture-improvement and as raw material for other starch-related products. In addition, starches can be modified to further increase their utility.

Tropical root crops that are currently used as commercial starch sources include cassava (Manihot esculenta, Manihot utilissima), yam (Dioscorea spp.), cocoyam (Xanthosoma spp.), taro (Colocasia esculenta) and arrowroot (Maranta arundinacea).

These crops have varying levels of starch, ranging from 19-40 %, differ in composition and consequently their properties in food products. Predominant areas of production, consumption and export are the Caribbean, Latin America, sub-Saharan Africa and Southeast Asia.

The demand for food starches continues to be high in industrialized countries, where processed food consumption is high and the food industry continues to be robust and vibrant. Applicability of starch in food products is determined by various factors: its composition, functionality and cost. Root starches, which have high amylopectin levels, are highly desirable as they have great clarity, minimal flavor and suitable water absorption and swelling capacity.

INTRODUCTION

Despite their extensive use as staples and as major food ingredients in the areas of production, most root starches are still largely underutilized in the global food industry. A major drawback that limits application of these starches in the target market is the lack of familiarity with the source food crops and the inadequacy of useful data on starch properties and attributes. Despite the availability of information on most root crops, specific data on starch characteristics of interest such as granule size and composition is greatly lacking. Their suitability in food applications is relatively unknown, and food companies

are unwilling to invest in research and characterization studies. Another challenge to tropical root starch use is the inconsistency is supply quality. Finally, lack of familiarity with source material translates to skepticism about consumer acceptance of root starch-based products in new markets. With these challenges, root starches lag greatly behind the grain starches.

Improvement efforts in the characterization of tropical root starches, and the establishment of desired quality will no doubt greatly contribute to their exploitation by mainstream, global markets. Furthermore, it is essential that indigenous technologies that diversify the utilization of root starches in multiple food applications, such as the use of cassava starch in baked products in the Caribbean, be enhanced and optimized. Finally, starch production and quality must be targeted to meet desirable standards of the industry. Such efforts will validate root starch quality and enhance its competitiveness in an increasingly demanding, but very robust global market.

TROPICAL ROOT STARCHES

Starchy root crops constitute dietary staples in most hot, humid tropical areas. Even though grain crops such as maize and legumes play a significant role in the diet, roots and tubers comprise the primary starch sources. Most common among these are cassava (yuca, manioc) (*Manihot esculenta, Manihot utillissima*), cocoyam (*Xanthosoma spp.*), taro (*Colocasia spp.*), sweet potato (*Ipomea batatas*), yam (*Dioscorea spp.*) and arrowroot (*Maranta arundinacea*) (Dufour *et al.* 1996; FAO, 1998; Hoover, 2001). (See Table 1). Sweet potatoes, cassava and taro are reported to have originated from tropical Central America (FAO, 1990). When freshly harvested, these are high in starch and moisture (Ene, 1992; Hoover, 2001). Being primarily starchy crops, most indigenous processes involve the removal of moisture, resulting in concentration of the starch. This in turn facilitates starch separation and packaging for industrial use.

Root crops play a significant role as cash crops and commodity crops in the tropics. They have competitive and even better monetary returns than their closest cash crop competitors such as sorghum and other grains (FAO, 1990). Yam for instance yields a gross monetary return of $1,469 per hectare, compared to $366 /ha for rice and $117 /ha for sorghum.

Starch is produced from root and tuber crops in a stepwise process that entails grating of the root, filtration of starch, followed by sedimentation, drying and milling (Ene, 1992; Badrie & Mellowes, 1992; Niba *et al.*, in press).

Starch, the industrial name for the white, granular carbohydrate, is composed of two constituent polymers - amylose, a straight chain polymer and, amylopectin, the branched polymer (BeMiller & Whistler, 1996; ISI 1999). Proportions of these polymers vary in plants. The ratios of these two polymers in a starch greatly influence the physico-chemical properties and utilization of the starch, as they in turn impact on water absorption, texture, and consequently behavior in a food matrix. High amylopectin starches are generally preferred for high viscosity products.

The fact that most tropical root crops have been tagged as subsistence crops or even, as in the case of cassava (yuca), a poor man's crop, most suited as a hunger crop in areas of abject poverty, but otherwise non-competitive as a cash crop, constitutes a dilemma for marketing root starches in new areas. They are often considered to be possibly unsuited for mainstream or in non-traditional applications, or even as starch bases in food products that affluent consumers would choose. Consequently, they are generally underrated, to the extent that even in areas of cultivation and consumption, industry processors would opt for imported, more readily-available grain starches as source material, further undervaluing root starches. Ene (1992) reports that as incomes rise in some developing countries, root crop consumption declines. Root starches have unique and highly desirable qualities, but there seems to be a gaping chasm between the industry processors and the source material. This is manifest to some extent by the prevalence and demand for waxy maize, a genetically-modified, high amylopectin maize developed to produce a starch with somewhat similar attributes to root starches. Other than potato (*Solanum spp.*) and cassava (*Manihot spp.*)

Table 1: Tropical Root Crop Starch Sources

Plant Source	Production in the Americas (million tons)	Yields (tons/ha)	Price (US$/ton)	% Starch (% amylase)	Food Applications
Cassava (yucca, manioc) (*M. esculenta, M. utilissima*)	28.5	8.8	70	35 [17 - 23.6]	Baked Sour starch, Beer/alcohol Farinha,
Cocoyam (*Xanthosoma saggittifolium*)	NA	4.2	123	19 - 35 [21-26.5]	Soup, biscuits, beverage
Taro (*Colocasia esculenta* schott.)	0.3	NA	NA	19 - 35 [23.7]	Flour, puddings
Yams (*Dioscorea alata, D. cayanensis, D.rotundata Poir*)	2.5	9.0	163	15 - 40 [17.7 - 29.7]	Flour (fufu)
Arrowroot (*Maranta arundinacea*)	NA	NA	NA	[19.4 -23.3]	Biscuits Sauce thickener
Potatoes (*Solanum tuberosum*)	12.9	10.9	142	32 [18.3 - 25.4]	Various
White fleshed sweet potato (*Ipomea batatas*)	2.4	7.1	89	25 - 40 [19.1 - 22.8]	Noodles, beverage (dolo)

Sources: Dufour et al., 1996; FAO, 1990; FAO, 1993; Hoover 2001; Huang et al., 2000; ISI, 1999; O'Hair, 1990; www.rbgkew.org.uk,

starches, which are widely used in the food industry, most root starches lag far behind. However, there is great potential for root starches. The cassava industry in Thailand continues to thrive as the premier producer and exporter of cassava starch, for instance, and in Vietnam cultivation of cassava as a source of starch is on the rise, despite an abundance of rice.

Despite fluctuations in world prices of starch, the demand continues to be high, as multinationals continue to seek for optimal and high quality materials. Standardizing root starches, which indeed do have various unique attributes and can fulfill various needs, will greatly add value and contribute to bridging the gap between producers and consumers in new, broader and more global markets.

STARCH APPLICATIONS IN THE FOOD INDUSTRY AND POTENTIAL MARKETS

Industry processors continue to seek high quality, consistent, multi-functional, yet affordable sources of starch. Starch has several functions in the industry as a food ingredient. It is used as a bulking agent, as a carrier, as a fat replacer in salad dressings and baked products, and as a raw material for syrup production. Starch constitutes the basic ingredients in food products such as breads, puddings, marinades, sauces, and is a less noticeable but equally vital ingredient in powdered spices, baby foods and various beverages.

The applicability and choice for utilization a starch is determined by various factors. Most important are its composition (ratio of amylose to amylopectin), and its functional properties, particularly viscosity and water binding capacity. These are particularly relevant as food processing conditions vary widely even for the same food product. Physical variables such as temperature, processing pressure and acidity could vary widely for different stages of production, packaging and distribution. As such, native starches may sometimes require modification to withstand these conditions. Capacity for modification of a starch is in turn, dependent on its structure and composition.

The predominant starch sources for industry use in the European Union and United States are maize, wheat and potato starch. Trade data indicates that several countries import over a billion dollars worth of cereal flours and starches annually, as well as considerable amounts of root and tuber related products (see Table 2).

In industrialized countries where production and consumption of processed foods is high, starch is a central raw material in the food industry, both as an ingredient, and as source material for other products. Starches with a wide range of functionality and use are highly desirable (Hegenbart, 1997). This implies that they would require less extensive modification, and so overall would be cheaper and more affordable. In addition, natural, unmodified starches appear to be more desirable for European consumers. Cornstarch is the primary starch source used in the food industry the United States most industrialized countries (Hegenbart, 1996).

In the United States, growth in utilization of industry starches for starch-derived products is projected to grow from 2%-3%

Table 2: Cereal Flours And Starches, And Root/Tuber Imports Among Some Major Countries (1998 And 2000):

Country	Cereal Flour/ Starch (1998) (US$'000)	Cereal Flour/ Starch (2000) (US'000)	Vegetable/Root /Tuber (1998) (US$'000)	Vegetable/Root /Tuber (2000) (US$'000)
USA (includes Puerto Rico, US)	1,472, 538	1,782,445	1,159,707	1,338,447
Japan	603,042	555,790	1,186,575	1,329,502
United Kingdom	1,018,226	961,846	962,905	819,060
Netherlands	356,032	423,748	321,897	345,166
Canada	615,291	695,559	316,430	316,424
Hong Kong	185,663	189,829	183,642	146,825
Brazil	310,426	205,249	185,117	117,799
Australia	117,822	159,127	104,166	114,030
Saudi Arabia	117,963	146,015	74,299	95,400

Source: International Trade Center, UNCTAD / WTO: http://www.intracen.org/tradstat

annually for use in sweeteners, to 8%-10% annually for citric acid (USDA-ERS, 1997; Sansavini and Verzoni, 1998). In the European Union meanwhile, use of starches by the food industry constitute almost 60% of all industrial starch use (see Table 3). This implies growth and potential for food starches.

Table 3: Starch Utilization in the European Union Food Industry

Industry	Utilization (%)
Sweets and drinks (Food Industry)	33 - 34
Processed foods	21 - 22
Chemicals & pharmaceuticals	16 – 16
Paper / card board	27 – 28
Feed	2

Source: Henry et al., 1998.

CURRENT CONSTRAINTS TO INDUSTRIAL USE OF TROPICAL ROOT STARCHES FOR FOOD APPLICATIONS

A primary concern with the purchasing and application of tropical root starches by the food industry a considerable lack of familiarity with the source material. There is therefore some cautiousness among industry consumers in choosing them for use in food applications.

Another major constraint is the inadequacy and lack of basic data and information of interest to food processors on most tropical root starches. There is considerable need for research and characterization of tropical root starches (Hoover, 2001). Data on production levels of starch is also sparse and quite limited (Henry & Westby, 1996; Henry *et al.*, 1998; FAO, 1998). With the exception of cassava and potato starch, research and publication on tropical root starch characteristics is still not readily available (see Figure 1). These two root starches have been most extensively studied and characterized, and this is probably linked to their considerably wide use and acceptability in the food industry. Other root crops are far less popular in new markets.

Without basic data that describes starch physicochemical characteristics and its potential in a food-processing matrix, food companies are unwilling to expend in research and characterization studies, particularly where there are alternatives, such as the grain starches.

The inconsistency in supply and quality of root starches make them unattractive as raw material for the food industry in larger markets. In addition, the absence of data on variables such as shelf-life and storage effects is a drawback to utilization and application.

Finally, the lack of familiarity with these starchy root crops, leads to a skepticism and reticence with regard to trying out these starches, either as ingredients in established products, or in developing new products with these starches.

While there continues to be a demand to meet the myriad of application of starches in the food industry, the demand for tropical root starches seems to be on the decline. World utilization of cassava, one of the two premier industrial root starch sources, for instance is projected to slow down from 4.7% in 1993 to 3.1% by 2005 (Henry & Westby, 1996; Henry *et al.*, 1998). In addition, the prevalence of scientific capabilities such as chemical modification of starches and bio-technology, which greatly facilitate manipulation of grain starches to extend their capabilities and hence applications, do not bode well for the demand for root starch sources. A pro-active and concerted approach is therefore needed to avert the potential sidelining of root starches, which could become irrelevant or of minimal significance in the market place.

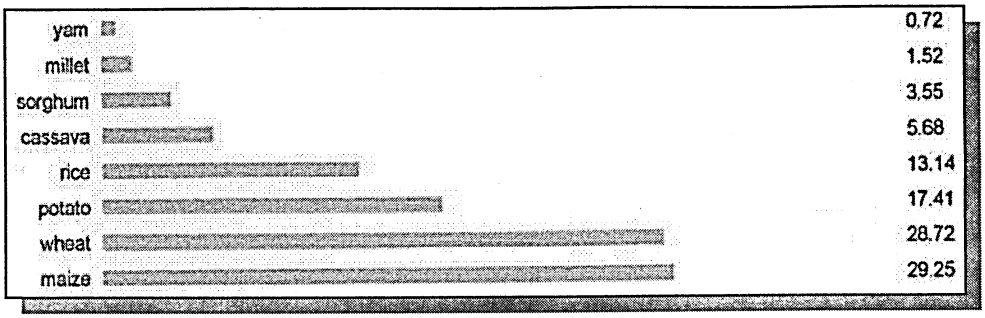
DIVERSIFICATION AND OPTIMIZATION OF TROPICAL STARCHES FOR FOOD APPLICATIONS

The global market continues to expand as consumers seek more diverse, but authentic and natural products. Root starches have unique, desirable and functional characeristics, which would greatly facilitate their incorporation in new products or as substitutes in traditional, more familiar food products.

The movement towards natural foods and unmodified foods in several industrialized countries, particularly in Europe, would provide new markets where consumers prefer an option to the genetically modified grain starches, which are prevalent. Furthermore, non-grain starches are also appealing to certain groups.

Prioritization of research and development efforts in root starch producing countries, to go further than just producing starch, but also to characterize starch and provide needed, relevant data with regard to starch quality, will greatly enhance utility of root starches (see Figure 2. Vital information such as starch composition, interactions and potential for use will contribute to their use and application. Phosphorus content of potato starch, for instance, is reported to be in a form that facilitates its water absorption, swelling capacity and clarity of starch pastes (Hegenbart, 1996). Similar data for tropical root starches will most certainly render them.

Figure 1: Percentages of Publications on Physical Properties of Various Starches Available through Food Science and Technology Abstracts Database: (adapted from FAO, 1998)



Source: http://www.fao.org/WAICENT/FAOINFO/AGRICULT/magazine/9809/spot3.htm

more attractive, competitive and viable in the market. Established quality screening protocols and assurance will further ensure consumer confidence.

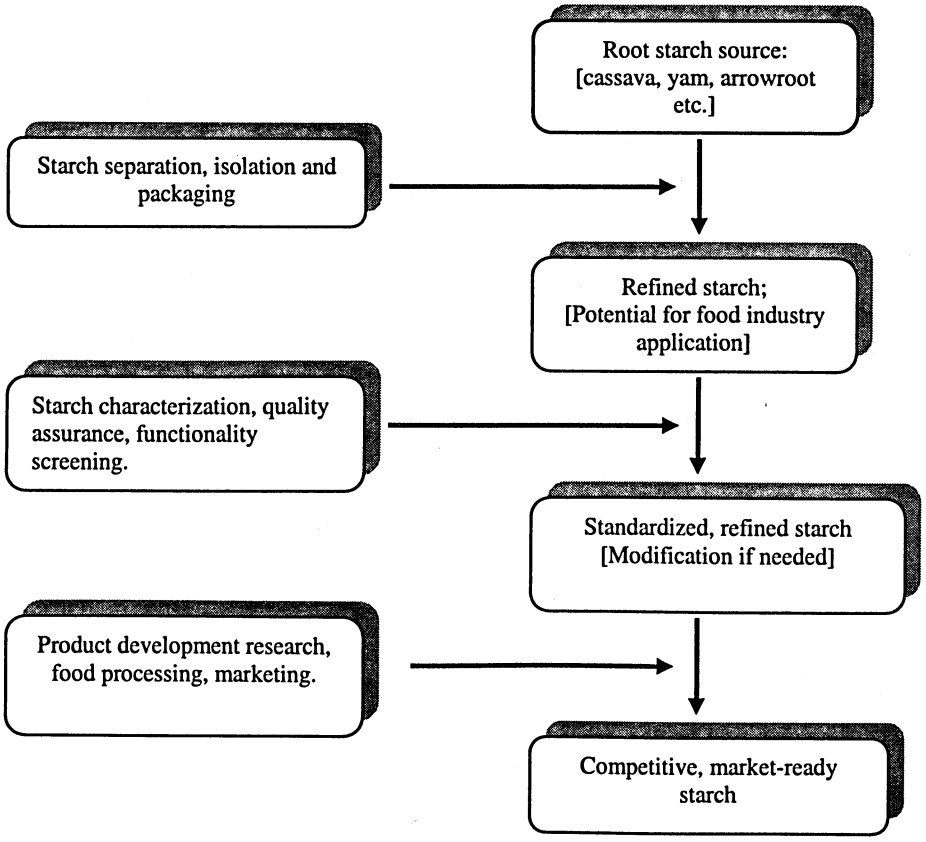
Secondly, indigenous technologies, most of which are under-utilized could be optimized and standardized to facilitate co-option of root starches for a mainstream, or if need be, a specialized, but global market. Established processes such as the production of beverages from cassava starch, and the use of taro starch in sorbets, could be improved for international markets. With urbanization trends on the rise in most developing countries there has been a push toward optimizing their raw materials for convenience, acceptability and profit. The incorporation of fermented cassava starch into milk beverages, for instance, to produce high quality processed foods, was shown to improve nutritional quality (Corte *et al.*, 2001). This is indicative of the potential of diversifying applications of root starches. Food product development as a prelude to processed foods production using these starches as raw materials will greatly enhance their use. Determining consumer acceptability will contribute to firmly establishing root starch quality. Despite the lack of familiarity, the success of 'brand name' starches such as tapioca starch from Thailand, could be a model example of the potential of root starches. Valid research data coupled with appropriate, targeted marketing will further augment the viability of these starches.

The cultivation and production of most starchy tropical root crops is relatively affordable. Cassava (yuca) requires minimal maintenance to produce considerable yields, as is the case with taro and most root crops. This indicates that there could be a reasonable expectation of consistency in the availability of source material. The challenge so far has been quality application and maximum utilization.

A concerted effort between producers, researchers and marketing specialists would most surely produce high quality, competitive starch for the expanding global

market where the demand and applications continue to be on the rise.

Figure 2: Quality Optimization of Tropical Root Starches for Global Utilization



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