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BARRIERS TO ADOPTING A DIVERSITY OF NUS FRUIT TREES IN LATIN AMERICAN FOOD SYSTEMS

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Introduction

Latin America is home to an extraordinary diversity of nutritionally important fruit-tree species (Kermath et al., 2014) and, for millennia, local people have selected and domesticated useful species in their landscape (Levis et al., 2018). Despite the high diversity of nutritionally rich fruit trees, the homogenization and Westernization of consumption patterns in the region have driven the spread of poor diets, particularly in rural areas. Diets, especially of Indigenous communities are increasingly based on staples and processed food with lower nutritional values (Coimbra et al., 2013). Farming in Latin America is increasingly based on unsustainable and environmentally damaging practices, which drive tropical forest degradation and deforestation (Dobrovolski et al., 2011). Over 80% of Latin American farms are managed by smallholders (Leporati et al., 2014), who are incentivized by policy initiatives to prioritize fruit cash-crops at the expense of on-farm diversity (Sthapit et al., 2016). Although crops such as palm oil *Elaeis guineensis*), cacao (*Theobroma cacao*) and banana (*Musa* sp.) can play an important economic role in the region, monocultures make farmers increasingly vulnerable to socioeconomic and environmental shocks (Maas et al., 2020).

The advantages of adopting a greater diversity of fruit-tree species clearly extend beyond economic resilience. One premise of this chapter is that ecological benefits, including restoration of landscapes and delivery of ecosystem services – carbon sequestration, pollination, soil protection, and fauna habitat connectivity – will be generated through increasing the role of underutilized fruit species in local, national and international markets. This will also contribute to the conservation of important genetic resources (vanHove and VanDamme, 2013; Thomas et al., 2018; van Zonneveld et al., 2020). In the Americas alone, there are several thousand fruit-bearing tree species with the potential to generate

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income and improve diets (Bioversity, 2004). Despite considerable evidence supporting their ecological, cultural, nutritional, and livelihood-related benefits (Santos, 2005; Jansen et al., 2020), many of these native fruit species remain neglected or underutilized (NUS). While it is clear that not all fruit species have the potential to become global market sensations, significant opportunities exist to increase the range of promising species at regional or national levels, improving community food security and local economies.

We reviewed a representative sample of 150 NUS across 27 families from various Latin American ecoregions. From this species list, we identify 25 high-potential species, considered to have the greatest scope expanding their commercial horizons (Table 7.1). We identify and discuss a range of barriers to adoption of native fruit-tree species, across farmer-facing obstacles, gaps in the value-chain and barriers in consumer demand (Table 7.2). We describe examples of how these specific barriers have been lifted in the past. Finally, we make suggestions on how these solutions can be extended to other contexts in the future, unlocking the potential of a broader range of Latin American biodiversity – thus meeting growing consumer demand for supply-chain transparency and benefiting farmers throughout the continent.

The barriers to adoption of NUS fruit-tree species in Latin American food systems

Multiple factors can inhibit the uptake of native fruit-tree species in diversified farmer production systems and consumers' diets (see Table 7.2). The barriers are compiled into three main categories: (i) farmer-facing constraints at the production stage; (ii) value-chain related obstacles and (iii) challenges related to consumer demand and marketability.

Barriers at production stage

On-farm challenges in fruit production can prevent farmers from adopting certain crops, thereby limiting the diversification of agroforestry systems. These challenges are often related to a lack of knowledge or capacity. In a study on native Amazonian fruit species selected for their high economic, social and ecological benefits, the identified barriers to adoption, whether for home consumption or as cash crops, were primarily socio-technical rather than market or profit oriented (Lagneaux et al., 2021). The most common limitations were, in order of frequency: lack of knowledge about the species, skepticism about productive potential given soil conditions, challenges related to harvests (e.g., in the case of tall palm species) and limited access to seeds and seedlings. This suggests that the factors keeping farmers from integrating more NUS fruit species are diverse and not exclusively economic.

For greater uptake of NUS it is helpful to understand which species are compatible with important commercial crops. Coffee in Central America is often

TABLE 7.1 Selection of 25 high-potential Latin American fruit-tree NUS along with their possible uses, current geographical distribution and recommended scale of market

Scientific name	*Family*	*Common name(s)*	*Primary product*	*Other products*	*Current geographical distribution in Latin America*	*Recommended scale of market*	*Description of primary barrier(s) to adoption*
Acca sellowiana	Myrtaceae	Feijoa	Fresh fruit	Processed fruit products (frozen pulp, puree, jams)	South America	International	Peculiar subtropical ecology of the species, which requires cold temperatures to fruit; sensitive to soil and microclimatic conditions of degraded drylands (e.g., dry tropical forest and highlands deforested to desert); strict cold-chain requirement
Annona cherimola	Annonaceae	Cherimoya, Custard apple	Fresh fruit	Processed fruit product (frozen pulp, puree)	South America (tropical highlands: Andean valleys)	International	Lack of public knowledge on its nutritional properties; relative fragility of the fruit itself
Annona muricata	Annonaceae	Soursop, Guanábana, Graviola	Fresh fruit	Processed fruit products (frozen pulp, puree); leaf powder (medicinal)	Caribbean, Central America, South America	International	Lack of public knowledge on its nutritional properties; underdevelopment of medicinal products (leaf powders); relative fragility of the fruit itself
Annona squamosa, A. squamosa x A. cherimola	Annonaceae	Sugar Apple; Atemoya	Fresh fruit	Processed fruit products (frozen pulp, puree)	Caribbean, Central America, South America	International	Lack of broad productive base; relative fragility of the fruit itself

Bertholletia excelsa	Lecythidaceae	Brazil nut, Castaña	Edible seeds	Seed oil (edible & cosmetics); timber (illegal throughout most of the species' range); medicinal resin	Southwestern Amazonia	International	Long-term duration of growth before maturity and fruiting can be a disincentive for planting; predation on planted individuals is frequent; most current production is from wild populations, limiting growth opportunities
Brosimum alicastrum	Moraceae	Manchinga, Ramón, Maya Nut	Edible seeds	Leaves (rich fodder in silvipastoral systems); timber; medicinal resin	Central and South America	National	Lack of awareness of the products' nutritional benefits – seeds for human consumption and leaves for animal fodder; lack of diffusion of silvopastoral systems
Caryodendron orinocense	Euphorbiaceae	Metohuayo, Cacay, Inchi, Tacay, Nogal	Seed kernel oil (cosmetics)	Edible seed; seed kernel oil (edible)	Western Amazonia	International	Underdevelopment of markets for this promising product (seed kernel oil)
Erythrina edulis	Fabaceae	Pisonay, Porotón	Edible seeds	Ornamental; living fence	Western South America, and Panama	International	Lack of harvesting technologies, possible issues with insect pests affecting per hectare yields, lack of experiences with intensive cultivation
Eugenia stipitata	Myrtaceae	Arazá	Processed fruit product (frozen pulp, puree)	Fresh fruit	South America	National	Relatively small yield of individual trees leads to understanding of species as "non-cash crop"; fast ripening, perishability, and presence of insects in pre-harvest fruit
Eugenia uniflora	Myrtaceae	Suriname Cherry, Pitanga	Processed fruit product (frozen pulp, puree)	Fresh fruit	South America (central and southern)	International	Relatively small yield of individual trees leads to understanding of species as "non-cash crop"; lack of marketing of fruit product

(*Continued*)

Scientific name	*Family*	*Common name(s)*	*Primary product*	*Other products*	*Current geographical distribution in Latin America*	*Recommended scale of market*	*Description of primary barrier(s) to adoption*
Euterpe precatoria	Arecaceae	Huasaí	Processed fruit product (frozen pulp)	Palm heart "cabbage"; timber (for crafts and construction); seeds for handicrafts; medicine (roots)	Amazonia	National	Lack of access to value-added processing equipment (cold-chain), complexity of harvesting (high canopy), unfamiliarity of the product
Garcinia humilis, G. madruno, G. macrophylla, Garcinia sp.	Clusiaceae	Charichuelo, Achachairú	Fresh fruit	Processed fruit product (frozen pulp)	Amazonia	National	Perishable fruits; lack of development of high value processed fruit products; lack of marketing emphasizing nutritional benefits, similar to its relative mangosteen
Grias peruviana	Lecythidaceae	Sacha Mangua	Fresh fruit	Nut milk or similar product; seed oil	Amazonia	National	Need for detailed nutritional analysis of oily coconut-like fruit pulp; lack of marketing and investment in development of novel products (nut milk, etc.)
Inga ilta	Fabaceae	Inga, Guaba Ilta	Fresh fruit pulp	Edible seeds; firewood; mulch and biomass	South America (Peru, Ecuador)	Regional	Germinated seeds and insects in pods make the fruit less attractive for direct consumption (and overall perishability); lack of value-added product attractive to consumers
Mauritia flexuosa	Arecaceae	Aguaje, Burití	Fresh fruit; fresh juice	Processed fruit product (frozen pulp, puree); seed kernel oil; pulp oil	South America (northern)	International	Limited amounts of fruit pulp per weight of fruit; consumer unfamiliarity with the fruit and derived products; traditional supply-chains associated with deforestation of the species for harvest

Myrciaria dubia	Myrtaceae	Camu Camu	Fresh juice	Processed fruit product (frozen pulp, puree); vitamin C supplements	South America (northern and western)	International	Premature harvest leads to low quality end products; Incomplete domestication leads to irregular, heterogeneous products; relatively small yield of individual trees leads to understanding of species as "non-cash crop"
Oenocarpus bataua	Arecaceae	Ungurahui, Patauá	Fresh fruit; fresh juice	Processed fruit product (frozen pulp, puree); seed kernel oil; pulp oil	South America, Panama, and Trinidad (Caribbean)	International	Slow growth; complexity of harvesting (high canopy); perishability of value-added product (pulp); lack of consumer knowledge about added-value products
Pouteria lucuma	Sapotaceae	Lucuma	Fresh fruit	Processed fruit product (flour, frozen pulp, puree)	Andean valleys	National; International (flour)	Low visibility on the international market; unwillingness of large players to promote fruits with underdeveloped supply-chains
Prosopis flexuosa, P. pallida	Fabaceae	Algarrobo, Huarango, Peruvian Mesquite	Processed fruit product (fruit syrup *algarrobina*)	Dried fruit pods; fruit pods for cattle feed in silvopastoral systems	Arid and semi-arid Andean and coastal valleys	International	Unfamiliarity of product for international consumers; sensitivity to soil and microclimatic conditions of degraded drylands (e.g., dry tropical forest and deforested highlands)
Theobroma grandiflorum	Malvaceae	Copoazú	Processed fruit product (frozen pulp)	Seeds for chocolate-like product; seed oil (butter)	Amazonia	International	Lack of processing equipment at farm-level; insufficient communication between key actors (farmers, producers, transporters, etc.)

TABLE 7.2 List of 25 barriers to adoption for Latin American fruit-tree NUS

Barriers to adoption of NUS fruit trees of Latin America	*Solution 1*	*Solution 2*	*Solution 3*
Availability: Barriers at the production stage			
Properties of fruit itself			
Perishability	Value-added on-farm processing (Frozen fruit pulp, sun-drying)	Other value-added processing (freeze-drying, making of jams)	Community-level education on nutritional benefits to increase the local consumption of fruits
	Example Species: *Theobroma grandiflorum*	Example Species: *Eugenia stipitata*	Example Species: *Perebea guianensis, Casimiroa edulis*
Presence of insects in pre-harvest fruit	Training farmers to harvest fruits at a proper stage of ripeness	Application of natural repellents: neem, hot pepper, etc.	Value-added processing methods (frozen fruit pulp, sun-drying, freeze-drying, jams)
	Example Species: *Chrysophyllum cainito, Pouteria caimito*	Example Species: *Anacardium excelsum*	Example Species: *Psidium guajava, Spondias bahiensis*
Incomplete domestication leading to irregular / heterogeneous products	Product transformation to hide irregularities of the raw fruit (value-added processing methods such as pasteurization and pures)	Plant breeding to complete selection of varieties for domestication, as well as grafting, to achieve more uniform, determinant fruiting	
	Example Species: *Eugenia involucrata*	Example Species: *Myrciaria dubia*	
Challenges on the farm (productive ecology)			

Long duration (10+ years) vegetative growth period before maturity and fruiting	Grafting of productive scions onto adequately managed rootstock results in precocious fruiting. Frequently seen in Latin America for cacao, mango, and avocado; the same technology can significantly increase the attractiveness to the farmer of a variety of species.	The creation of successional agroforestry systems provides short-term crops alongside a second tier of crops productive after two to eight years. Long-term crops are much more likely to be successful when planted among crops offering more immediate returns. The productivity of the parcel in time incentivizes and facilitates the establishment of long-term crops.	Seed selection of precocious individuals.
	Example Species: *Bertholletia excelsa, Eugenia uniflora*	Example Species: *Bertholletia excelsa, Dipteryx sp., Pseudolmedia macrophylla*	Example Species: *Hymenaea courbaril, Juglans neotropica*
Predation of planted seedlings by common local fauna (especially rodents), including peeling or ringing of bark, breaking of principle root or main growth leader, etc.	Implement herbivore protection mechanisms: physical barriers, such as stakes set in a dense "fence" around seedling; placement of netting or shade cloth; etc.	Implement herbivore protection mechanisms: biological deterrents or repellents (such as fermented hot pepper, black pepper, and garlic mix, application of neem or copper sulfate, and vinegar or sugar water fly traps; etc.).	
	Example Species: *Bertholletia excelsa*	Example Species: *Juglans neotropica*	
Pests and diseases	Understanding pest/disease ecology and apply biological control and/or targeted chemical mechanisms	Physical barriers for fruit protection such as bagging of banana racemes	
	Example Species: *Annona muricata, Solanum betaceum*	Example Species: *Eugenia stipitata, Annona muricata*	

(*Continued*)

Barriers to adoption of NUS fruit trees of Latin America	*Solution 1*	*Solution 2*	*Solution 3*
Complexity of harvesting (high canopy, thorns, irregular fruiting, etc.)	Development and/or implementation of harvesting tool technology (e.g., telescopic-cutting device). For palms in particular: encouraging the harvest without falling the palm by climbing or usage of harvest tool technology	Development of an adequate pruning regiment for more compact architecture	Grafting and artificial selection for more compact mature individuals
	Example Species: *Astrocaryum murumuru, Euterpe precatoria, Bactris gasipaes*	Example Species: *Matisia cordata, Theobroma grandiflorum*	Example Species: *Matisia cordata, Helycostilis tomentosa*
Relatively small yield of individual trees, or limited seasonality, leads to understanding of species as "non-cash crop"	Crop is treated as just one productive component in a diversified agroforestry system, including either a primary cash crop or a broad diversity of species that each produce modestly. Non-fruit trees (such as for timber and medicine) are included. Demo/model farm plots for farmer capacitation visits are established (selected or created) by corporate, NGO, or public actors.	Establishment of publicly accessible demonstration plots for various diverse agroforestry systems that yield profitable production while including otherwise individually-neglected species. Proper signage and/or in depth educational tours accompany the areas themselves.	Interventions at a level of plant breeding and selection. Participatory selection and breeding of most productive genotypes; management of pollinators and consideration of hand pollination (where economically viable).
	Example Species: *Eugenia biflora, Lecointia amazonica, Theobroma bicolor*	Example Species: *Platonia insignis, Myrciaria tenella*	Example Species: *Grias peruviana, Myrciaria dubia*

Lack of access to productive ecologic knowledge (How, when and where do you plant which tree? How productive is it at what age?) due to limited knowledge transfer among farmers, practitioners, and research institutes	Knowledge-spreading platforms: seed-sharing events, farmer field schools, farmer horizontal knowledge exchange; events oriented toward farmer's associations or cooperatives as well as individuals; working groups on specific underutilized species that bring together actors from all sectors.	Production of more practitioner-friendly learning resources (e.g., species technical sheets on productive ecology, adapting existing tools such as "Agroforestree" database from ICRAF, ECHO Community, Agroforestry.net species sheet, etc.); and making them available to farmers (e.g., free and accessible online, sharing them through outreach programs).	Creation of bridges across national research institutions (e.g., IIAP in Peru, Embrapa in Brazil, etc.), research organizations (e.g., NGOs CINCIA in Peru, Herencia in Bolivia) and local/regional governments in order to transfer evidence-based tools for the development of diversity-friendly policies and interventions.
	Example Species: *Theobroma bicolor, Myrciaria dubia*	Example Species: *Oenocarpus bacaba, Brosimum alicastrum*	Example Species: *Euterpe precatoria, Mammea americana*
Products primarily derived from wild populations rather than plantations, making harvest costly and challenging	Development of new approved management plans for harmless harvest of Non-Timber Forest Products (NTFPs) in forestry concessions and protected areas	Enrichment planting in primary and secondary forest areas; in agroforestry system orchards	Identification of wild productive forests in the territories of native or *campesino* communities, harvest by and for community members
	Example Species: *Euterpe precatoria*	Example Species: *Bertholletia excelsa, Carapa guianensis*	Example Species: *Oenocarpus bataua, Mauritia flexuosa*
Poor plantation performance due to degraded, contaminated and/or poor soils	Planting design considerations: extra high planting density, successionality, basic earthworks (swales, large planting holes), cover crops, tutor species, irrigation and shade, desert and drylands reforestation technologies (e.g., polypropylene plant cocoons and other self-irrigation mechanisms), etc.	Agroforestry systems including organic matter-producing and nitrogen-fixing fruit-tree species.	Public and private farmer-facing programs emphasizing on-farm fertility: compost production, breeding of beneficial indigenous microorganisms, locally available organic agricultural inputs such as rock phosphate and bird or bat guano, etc.
	Example Species: *Prosopis flexuosa*	Example Species: *Acca sellowiana*	Example Species: *Annona muricata*

(*Continued*)

Barriers to adoption of NUS fruit trees of Latin America	*Solution 1*	*Solution 2*	*Solution 3*
On-farm infrastructure			
Difficulty of germination or propagation for certain species, meaning farmers have limited access to seedlings and are unable to successfully propagate their own seedlings without specialist nurseries	Dissemination of knowledge on how to establish nurseries, ideally with the use of local materials and familiar or appropriate design. Community- and family-level nursery can be developed by NGO, governmental, or corporate initiative. The cost of widespread nursery establishment may require financial mechanisms designed to recognize the value of seedlings produced in the nurseries over time.	Establishment of public and private nurseries operating at adequate volume to produce seedlings at low cost. Public programs oriented toward making nursery products more accessible to farmers.	Corporate supply-chain programs, in which farmers supplying raw materials are incentivized to enhance on-farm diversity, including the delivery of seedlings for species that are challenging or costly to propagate.
	Example Species: *Bertholletia excelsa, Juglans neotropica*	Example Species: *Grias peruviana*	Example Species: *Bertholletia excelsa*
Lack of accessibility to farm sites by vehicles, impacting farm and market access for farm products, especially perishable ones, and ease of delivering seedlings to farm	Supply-chain investment in innovative alternative means for scaling delivery and distribution of seedlings and reception of farm products. In some rural areas, motorcycles and beasts of burden can provide solutions. Examples in the Amazon region include investment in boats to purchase farm products directly from inaccessible producer communities.	Public investment in appropriate transportation systems, such as public boat transportation systems in regions with navigable rivers and few roads. Construction of alternative roads, such as motorcycle-accessible gravel paths that avoid some of the pitfalls of the environmental and social impacts of large road construction, including increased deforestation and delinquency.	Empowerment and financing of cooperatives to allow efficient accumulation and transportation of the goods of various farmers. With greater scale of production, short-term investments such as truck hire for transport of goods to market are justifiable and financially feasible.
	Example Species: *Annona sp.*	Example Species: *Euterpe sp., Pourouma cecropiifolia*	Example Species: *Euterpe sp., Theobroma sp.*

Lack of on-farm infrastructure that would allow the extension of species' geographical range, such as irrigation systems; and related financial constraints	Public investment in infrastructure, such as agricultural water access via pipelines that extend urban grids into rural areas; and preferably decentralized solutions such as motor pumps and hoses for individual farmers in areas with river or stream access.	Dissemination of knowledge and appropriate seed varieties for dry farming. Use of grafting with naturalized and native rootstock.	Planting design considerations: extra high planting density, basic earthworks (swales, large planting holes), cover crops, tutor species, irrigation and shade
	Example Species: *Myrciaria dubia*	Example Species: *Prosopis flexuosa*	Example Species: *Vasconcellea pubescens*
Accessibility: Barriers at the value-chain stage			
Supply-Chain Side			
Current lack of a promising, known value-added product that is attractive to consumers and is shelf-stable	Innovation in product development (e.g., flour, oil extraction, pulp)	Innovation in value-added processing (cold-chain for frozen pulp, jams, freeze-dried products)	Creation of regional innovation/think hubs connecting local people and creating and also financing innovative activities (startups, knowledge exchange, etc.)
	Example Species: *Inga sp., Perebea guianensis*	Example Species: *Mammea americana, Solanum betaceum*	Example Species: *Ugni molinae, Theobroma speciosum*
Lack of access to value-added processing knowledge and equipment (e.g., cold-chain infrastructure)	Farmer outreach programs that support the development of value-added products that can be processed on-farm simply and inexpensively: purees, marmalades, dried fruit, jams	Producer associations with robust governance that manage processing equipment, infrastructure, vehicles for transport for market, and other capital considerations. These association can be directly linked with the buyers of specific products.	Knowledge transfer of cost-effective and available methods for fruit transformation to transportable and non-perishable products; from technical institutions to farmers, e.g., through increased collaboration between farmer association and local institutions
	Example Species: *Theobroma grandiflorum, Eugenia stipitata*	Example Species: *Myrciaria dubia*	Example Species: *Theobroma bicolor*

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Barriers to adoption of NUS fruit trees of Latin America	*Solution 1*	*Solution 2*	*Solution 3*
Prohibitive costs of production	Improved collaboration (e.g., cooperatives) between farmers to organize and finance processing equipment, materials, ingredients and increase processing capacity. Example Species: *Astrocaryum murumuru, Carapa guianensis*	Access to public or private investment (loan, funding, etc.), productive and technological support by governmental institutions Example Species: *Euterpe precatoria*	
Informal and inadequate transportation from farm to market (e.g., for fruit pulp)	Coordination between farmers to organize and finance transport to village hub locations with cold-chain adequate means of transport (e.g., truck with cold chamber). Example Species: *Euterpe precatoria, Spondias bahiensis*	Access to funding for cold-chain adequate means of transport. Example Species: *Poraqueiba sericea, Pourouma cecropiifolia*	
Market side			
Lack of a sufficient productive base to support scaling to satisfy a larger market; challenges of promoting new species without a strong existing market	Municipal nurseries, private sector investment in propagation and diffusion of seedlings; connection of these efforts directly to buyers and processors of the raw materials Example Species: *Pouteria lucuma, Sambucus peruviana*	Large promotion campaigns a large company or many SMEs Example Species: *Theobroma speciosum*	
Acceptability: Barriers in consumer demand and marketability			

Unfamiliarity of product and product's nutritional benefits to local/regional consumers	Public campaigns: diffusion of seedlings; knowledge transfer from science to markets Example Species: *Poraqueiba sericea*	Engagement with public health and education institutions (e.g., Ministry of Health, Ministry of Education) for the distribution of publicity/educational materials around the fruit's benefits in municipal markets and schools Example Species: *Myrciaria dubia, Euterpe precatoria*	Form a growers' association that works in collective to penetrate new markets; and promote processing to frozen pulp for placement in school lunch and other public food programs as well as private sector sales. Example Species: *Oenocarpus bataua, Euterpe precatoria*
Popular perception of traditional crops as incompatible with economic or cultural progress; preference for introduced competing fruit species considered more "prestigious"	Public campaigns promoting local products Example Species: *Spondias bahiensis*	Use of new marketing tools, e.g., promotion by influencers, adoption by celebrity chef Example Species: *Poraqueiba sericea*	Governmental support to increase production volume, reach competitive market prices and facilitate market access Example Species: *Mauritia flexuosa*
Unfamiliarity of product to international consumers	Promote familiarity on local market as a basis for international promotion. Example Species: *Mauritia flexuosa, Oenocarpus bataua*	Flagship brand communicating heavily about nutritional benefits (like "superfoods" and Sambazon for Açaí). Example Species: *Pouteria lucuma, Theobroma bicolor*	Adoption by recognized company/ brand(s) (e.g., Coca-Cola for açaí) Example Species: *Theobroma speciosum*
Competition with other exotic fruits with an existing reputation (Mango, Passion fruit, etc.)	Promotion campaigns Example Species: *Schinus molle, Vasconcellea pubescens*	Find niche markets, where customers are attracted to unknown tastes (e.g., Latin American restaurants) Example Species: *Ugni molinae*	
Preference to locally produced or regionally existing fruit products, rather than import of novel and unfamiliar products from other regions	Raising awareness of the social and ecological value related to NTFP produced in Latin America Example Species: *Euterpe precatoria*	Ensure energy efficient transport and low carbon footprint (ship freight) and inform customers about it Example Species: *Pouteria lucuma*	Inform customers about the nutritional value of the fruit Example Species: *Eugenia uniflora, Mauritia flexuosa*
Short time window between fruit harvest in tropics and summer market peak in US and EU	Promotion of less season-specific end products. Example: Salty dishes, desserts others than ice cream **Example Species:** *Eugenia uniflora*	Irrigation systems Example Species: *Myrciaria dubia*	

interplanted with fruit species that are complementary in terms of size and ecology, such as guava (*Psidium guajava*) and hog plum (*Spondias mombin*) (de Sousa et al., 2019). However, in many cases, in-field compatibility among fruit species may be limited; therefore, optimizing the designs of farm parcels is crucial to achieve successful outcomes. The lack of agronomic knowledge is also a significant barrier to the adoption and success of NUS – albeit one that can be overcome with training and horizontal knowledge sharing among farmers, such as in farmer field schools (see section 3).

Decision-making on which species to plant is sometimes influenced by the time it takes for a species to become productive. The Amazonian Brazil-nut tree (*Bertholletia excelsa*) for example is a hyper-dominant species, delivering multiple ecosystem services (Thomas et al., 2018). However, the trees only become profitable after 15–20 years or more and concerns in the region about its future market viability are increasing despite some enrichment planting (Bronzini, 2019). The investment required to bring this species to productive age may discourage its use when other species can deliver returns quicker. This serves to illustrate how a species' ecology – and the level of knowledge thereof – can act as barriers to adoption, in this case by smallholders in the Amazon.

Barriers at the value-chain stage – from farm to market

Two of the most significant challenges faced by smallholders in rural areas are post-harvest storage and the transport of fresh fruit to market. Given the perishability of many tropical fruits, processing them into value-added products with longer shelf-life is crucial for producers to fully benefit from the economic potential of these species. Farmers often face basic infrastructural limitations such as lack of electricity or potable water, restricting fruit processing options (Smith et al., 2007). Many fruits are never folded into even local market supply-chains due to the simple lack of transportation access to those markets, despite the fruits being delicious and highly nutritious. Fruits are typically moved at the farmer's expense by boat, motorcycle or truck to intermediate buyers, leading to less profitable transactions and an increased risk of damage to the product, resulting from a lack of operational cold chains. Consequently, market opportunities for fresh fruits are often extremely limited, and improvements to on-farm processing are needed for the development of viable fruit value-chains. Fresh copoazú (*Theobroma grandiflorum*), a relative of cacao, has a rather short shelf-life, perishing only four days after fruit-drop if it is not cold stored or processed. Other fruits are even faster to lose their color or flavor after harvest. For such species, the constant monitoring of trees, quick harvests and rapid transport to the closest local market are required in the absence of on-farm infrastructure.

Another Amazonian fruit, camu camu (*Myrciaria dubia*), prized for its outstanding nutritional value (Rodrigues et al., 2001), requires careful handling for optimum quality. If harvested semi-ripe, the fruit contains high amounts of vitamin C – the highest of any fruit – but its color and flavor are less attractive.

Harvested ripe, it possesses an impressive color and flavor, but the vitamin C content is less stable. Promoting fruits such as camu camu requires research and investment in more sophisticated fruit processing capacity, which, in this example, would enable the stabilization of vitamin C while also preserving organoleptic qualities.

Barriers in consumer demand and marketability

Many native fruits are unknown to urban consumers, hampering their inclusion in national diets. In big cities, fruit consumption is often limited to conventional, familiar fruits. Even though copoazú and Brazil-nuts are major income generators in the Peruvian Amazon, they are almost unknown in the capital Lima, where their consumption is surpassed by strawberries and almonds. This was also historically the case for camu camu – until 2019 when the Aje Group, Peru's largest soft-drink company, carried out a national publicity campaign and established the fruit as the main ingredient in a beverage on the market. This example demonstrates the impact that effective awareness-raising and marketing can have on increasing the visibility of NUS fruits. Public institutions can also play an important role in educating the masses on the benefits of a variety of locally produced fruits – for example, municipalities organizing cultural and gastronomic events.

On the other hand, consumer preference for local fruits in the Global North can amount to an obstacle to the promotion of underutilized Latin American fruits in international markets. This is mainly because of concerns about sustainability, the carbon footprint of airfreight and the lack of transparency of supply chains in remote countries. Novel tropical-fruit products can benefit from expanding conscientious markets (Jansen et al., 2020); consumers are increasingly demanding ethically sourced products that demonstrate traceability and provide guarantees of ecological sustainability and social fairness. Value-chains in which brands and retailers are committed to tracing fruits back to farmers can provide powerful incentives to continue growing native fruit species. A new product is mainly successful when it offers great taste, high quality and competitive pricing, but marketing can also break through by focusing on nutritional, social or environmental benefits.

The removal of barriers to adoption of native fruit-tree species in Latin American food systems.

For any particular NUS, multiple barriers to adoption are often present. The removal of one significant barrier can sometimes be sufficient to unlock the potential of a species. We do not necessarily need to confront all barriers to adoption to effectively address crucial bottlenecks.

Farm-facing solutions: In general, the removal of on-farm barriers requires engagement, working closely with farmers at each stage in the production process.

This is especially the case when scaling-up diverse farming systems, where long-term species are intercropped with short- and medium-term income-generating species – successional agroforestry. Government and other programs can help reduce the risk of traditional cultivars being replaced with monocultures by promoting diverse agroforestry systems with multiple perennial species, such as in the case of cacao cultivation in Central America (de Sousa et al., 2019). Diversity fortifies resilience, both on the farm and in the market, yet does require effective decentralized platforms for delivery of technical support, capacity building and knowledge transfer on species selection, planting design, management and harvesting strategies. Agronomic knowledge on the compatibility and complementarity of different native fruit species in agroforestry systems also needs to be more widely available and horizontally shared.

Finally, gaps in infrastructure and know-how for propagation (nurseries) and distribution in rural, remote areas with limited accessibility must be addressed if promising species are to be widely adopted. In the example of cherimoya, access to selected cultivars in combination with improved management (e.g., introduction of new pruning approaches) has resulted in increased incomes for Andean farmers in Peru, Ecuador and Bolivia (Vanhove and Van Dammel, 2013).

Another example is ramón (*Brosimum alicastrum*), a hyper-dominant forest species that is now embraced by local communities in the Maya Biosphere Reserve in Guatemala. Community- and farmer-facing outreach focused on the economic and nutritional benefits of new fruits is fundamental to the success of such non-profit programs. At the same time, the organization of fruit harvesters in associations – in this case with the collaboration of associations such as Asociación de Comunidades Forestales de Petén and NGOs like Rainforest Alliance (Izabela et al., 2019) – can be key to hitting export volumes and for successful co-investing in necessary infrastructure.

Value-chain development: A critical aspect of fomenting the adoption of native fruit species is the provision of economic incentives to farmers through reliable and equitable value-chains. In parallel, ensuring a consistent product through processing is critical to resilient value-chains. In Latin America, numerous examples of successful fruit processing exist, including pulp, dried fruit, flour, jams and freeze- or spray-dried powders (e.g., Moraes et al., 1994). All these added-value mechanisms help remove fruit transport barriers, though each has its own disadvantages. For example, the production of freeze-dried powder requires expensive equipment and fruit pulps need strict cold chains; meanwhile, jams are niche products with low overall consumption and demand. Opportunities exist for private and public sector actors to innovate. One alternative for overcoming fruit durability and transport barriers while preserving most of the fruit's natural features is the production of purees, a pasteurized form of fruit pulp that is highly versatile and can be used as an ingredient in a variety of final products. Puree is simple and cost-efficient to process and it can be stored and transported without a strict cold-chain. This is a solution that can be managed at the farm-level, keeping the added value of fruit processing in the hands of farmers.

Many of Latin America's most economically significant trees provide other commodities such as seed oil for cosmetic or edible use. Brazil-nut, murumuru (*Astrocaryum murumuru)*, and andiroba (*Carapa guianensis*) are just a few of the many native seed oils that have been successfully commercialized in Brazil (Plowden, 2004; Campos et al., 2015; Smith, 2015). Basic equipment – in this case oil presses – is all that is needed to enable small producers or cooperatives to offer value-added products to national markets. When this barrier – lack of access to capital or know-how for value-added equipment – is removed, fruits that previously were left to decompose on the forest floor can incentivize sustainable management of natural forest resources and the augmentation of wild production via agroforestry planting. In the example of Brazil, accessible financing terms are offered to farmers for investment in equipment and infrastructure (Machado de Moraes, 2014). Economic policies that promote the establishment of village-level infrastructure and development of local market-facing supply chains play a key role in successfully lifting a species from NUS status. The establishment of robust cooperatives or producer associations can help secure financing for equipment and strengthen producers' negotiating power with buyers and is, therefore, a vital component of fair trade certification standards – ensuring consumer satisfaction while also making a compelling argument for the consumption of unique fruits from distant regions.

Up-scaling NUS access to consumers: The Amazon is home to a rich diversity of palms that are extremely abundant producers of nutritious and culturally significant fruits. The pulp of açaí (*Euterpe oleracea*) is now a globally consumed, antioxidant-rich "superfood" that was traditionally prominent in the forest economy and food security of the lower Amazon basin (Muñiz-Miret et al., 1996). This product became known beyond Brazil's borders thanks both to well-positioned flagship brands in foreign markets (such as Sambazon in the US) and to a range of policies that support farm- and village-level producers (OECD, 2011).

In addition to açaí, acerola (*Malpighia glabra*), burití (*Mauritia flexuosa*) and copoazú have reached markets beyond the Amazon basin, but the lesson learned from Brazil suggests that establishing domestic as well as international markets is important for the creation of resilient value-chains. Brazil boasts a tremendous diversity of effectively domestically marketed products from the Amazon bioregion that remain underutilized in neighboring Peru, Bolivia, Ecuador and Colombia, presumably due to a lack of similar national economic policies. Species that remain underutilized throughout their native range but which have been developed in Brazil include peach palm (*Bactris gasipaes*), pama (*Pseudolmedia macrophylla*), pitanga (*Eugenia uniflora*), patauá (*Oenocarpus bataua*) and charichuelo (*Garcinia madruno*).

Governmental organizations, NGOs and Brazilian agricultural research institutes have promoted the consumption of native fruit species, resulting in the publication of a national ordinance that officially recognizes the nutritional value of more than 60 native food plants (Beltrame et al., 2016). With this policy support, federal and local governments have been able to achieve the inclusion of several fruits in subnational and local school lunch programs. Farmers who supply these programs are able to diversify their farms with nutritious food plants because the officially mediated procurement market incentivizes them to do so (Wittman and Blesh, 2017). Significant secondary benefits are achieved by introducing NUS in such school lunch programs, enhancing cultural acceptance and leading the way to the development of more robust local economies for these fruits.

The promotion of new fruit products in national or international markets requires investment. For successful adoption, knowledge about the fruit diversity of a region must be shared among producers, practitioners and distributors and with food businesses, including restaurants and end-consumers. Food fairs such as Lima's massive Mistura Food Festival, academic presentations and social events are just some of the many platforms that can be used to promote new tastes and raise awareness of the nutritional, social and ecological values of fruits. A key component is the involvement of adequate first-market adopters including tastemakers and celebrity chefs such as Virgilio Martinez and Pedro Miguel Schiaffino, two of Latin America's most important voices currently at the intersection of gastronomy and biodiversity. Successfully promoting new and exotic tastes involves customers that are curious and open, for example, to exotic and innovative cuisine, as found in some of Latin America's top-ranked restaurants. To reach these customers and further broaden these fruits' clientele, creative cultural solutions are needed – a challenge that is multifaceted yet of great importance if broader acceptance of unfamiliar fruits is to be achieved.

Conclusion

The barriers to adoption for underutilized fruit species in Latin America are as complex and diverse as the fruits themselves. The challenges in mainstreaming these fruits in food systems span from on-farm barriers, such as a lack of infrastructure or knowledge, to gaps in the value-chain, such as inability to process, stock or transport raw material, to lack of consumer demand because some products are not affordable or accepted. Heterogeneous and unfamiliar products struggle to scale up market access and consumer awareness. There are burgeoning examples of native fruit species that were, until recently, underutilized, but that now provide much-needed sustainable livelihood options for rural communities across the region. As demonstrated in this chapter, innovative processing systems, social institutions, ethical consumption and awareness-raising all play a role in lifting barriers (Table 7.2), to establish more resilient agroecological systems using the extraordinary genetic diversity of Latin American fruit-tree species. To synergistically contribute to income generation, diet diversification and resilient landscapes, poly-cultural food production using a greater diversity of fruit trees generates benefits from the local to the global scale. Simultaneously, better social outcomes are achieved, such as the creation of diverse diets with increased fruit consumption and associated public health improvement, development of more resilient farming systems, enriched livelihoods and the strengthening of local food security in cases of catastrophes. The diversity of fruits in Latin America is considerable and, while often overlooked, has the potential to help farmers overcome many of the biggest challenges they face. In order to unlock this transformative potential, practitioners from all sectors – governments, academia, businesses and NGOs – must collaborate on generating and sharing the practical knowledge of successes and failures that represents our most viable strategy for diversifying the food system.

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