Project Nº: **0015279**

Project acronym: **PAVUC**

PRODUCING ADDED VALUE FROM UNDERUTILISED TROPICAL FRUIT CROPS WITH HIGH COMMERCIAL POTENTIAL

Instrument : **Specific Targeted Research**

Thematic Priority: **Priority 5, Food quality and Safety**

PUBLISHABLE FINAL ACTIVITY REPORT

Period covered: **01/12/2008 to 30/11/2009** Date of preparation:**15/01/2010**

Start date of project: **01/12/2005** Duration: **4 years**

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Project coordinator organization name: **CIRAD** **(International Centre for Research in Agronomy for Development)**

Revision [ ]

Producing Added Value from Under-utilised fruit Crops

TITLE: **Producing added value from under-utilised tropical fruit crops with high commercial potential (PAVUC)**

1. PROJECT EXECUTION

Project summary: The PAVUC project aimed to add value to nine underutilized fruits of local commercial importance in three types of underdeveloped regions in Latin America (humid forest, dry areas, and tropical highland). The fruits were chosen for their commercial potential as biodiverse functional foods in the European market. They are tropical highland blackberries (*Rubus* spp.), naranjilla (*Solanum quitoense*), and tree tomato (*Solanum betacea*) which are produced in the hillside regions of the Andes and Mexico; red pitahaya (*Hylocereus* spp.), berrycactus (*Mirtillocactus* spp.), and cashew apple (*Anacardium occidentale*), cultivated in the dry regions of Central America, northern Mexico, and Brazil; and, finally, camu-camu (*Myrciaria dubia*), açaí (*Euterpe oleracea*), and peach palm fruit (*Bactris gasipaes*), produced in the Amazon Basin and coastal humid regions of tropical America.
Four research centres from Latin America and four from Europe were involved in this project, which was coordinated by the Centre for International Cooperation in Agronomic Research for Development (CIRAD), France.

Project objectives: The project's main objectives corresponded to five work packages (WP):

1. Assessing the biochemical composition, and real nutritional and functional potential of the selected fruits and their derived products (WP 1)
2. Understanding the production chain, identifying strengths and weaknesses, and formulating an action plan. The plan would be based on socio-economic studies on implementing innovations to improve agronomic and postharvest practices, and quality and safety along the agrifood chain (WP 2)
3. Developing appropriate processes to prepare fruit-derived products that meet the international market demand for novel biodiverse-and-functional foods or food ingredients (WP 3)
4. Identifying the European demand for biodiverse novel foods and assessing the real economic potential of some derived products selected by the project (WP 4)
5. Developing tools for disseminating information generated by the project to stakeholders and the general public (WP 5)

Contractors involved

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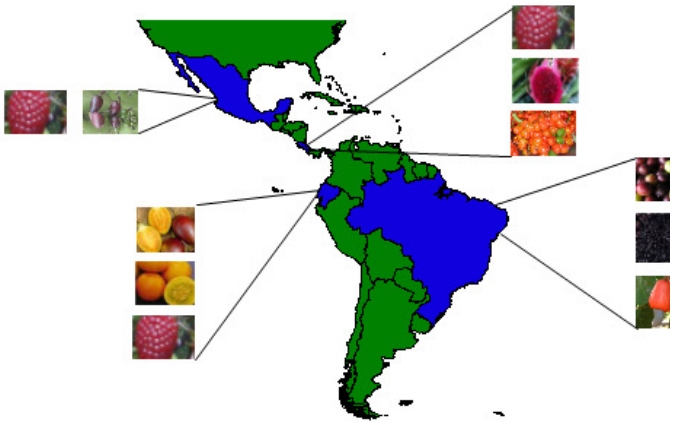


Summary of work performed and end results

Knowledge of the nine underutilized species has been considerably enhanced since the PAVUC project began in 2006. Much information has been revealed about these species, from the fork to the mouth and beyond, including their composition, potential functional properties for human health and possible impact, their production potential, organization for markets, processing of innovative products, and market expectations on both sides of the Atlantic.

In terms of composition, a database was completed, using parameters such as average contents of relevant phytochemicals in mature fruits, at different stages of maturity **(figure 1)** (*1*), during post-harvest storage (*2*, *3*), and for some processed products. Almost all nine fruits were found to constitute rich sources of molecules that would potentially benefit human health and which are usually scarce in Western food diets. Thus, their high potential for use as ingredients to increase the quality of processed food products was confirmed.

a. Tropical highland blackberry

b. camu-camu

c. açaí,

Fig 1. Different maturity stages of 3 PAVUC fruits

More specifically, phenol compounds were characterized for tropical highland blackberry grown in Mexico, Costa Rica, and Ecuador (*4*, *5*); açai palm (*6*); tree tomato (*7*, *8*); naranjilla (*7*, *9*); camu-camu (*10*); and cashew apple (*11-13*). Carotenoids were identified in tree tomato, naranjilla, cashew apple (*14*) and peach palm, while betacyanins were characterized in berrycactus (*15*) and pitahaya. Additionally, the antioxidant capacity of all fruits was assessed, although often following different methods (*1*, *6*, *7*, *14*, *16-20*). Moreover, a new method for assessing *in vitro* cellular antioxidant activity was developed specifically for PAVUC fruits (*21*). This was the first time for most of the fruits to have undergone such a complete characterization. Results were therefore widely disseminated through scientific publications and meetings.

The impact of consumption of the tropical highland blackberry on human health was also assessed through a clinical study. Results showed that this fruit can protect healthy volunteers against a challenge diet rich in fats and carbohydrates. In this particular case, surprising results were obtained such as significant reduction of lipid profiles. These results were disseminated through local press media, resulting in an immediate increase of fruit sales at the regional level. Also dissemination to the international scientific community is underway.

Indeed, some of the nine fruits were deemed to be so promising that industries in Latin America and Europe adopted, or are about to adopt, innovations proposed by the PAVUC project to respond to the growing demand for healthier food products.

To overcome possible hurdles along the supply chain and respond to possible expansion of demand and quality, production chains of all these underutilized crops were studied at the regional level. Although the production chains were at different developmental stages, a complete survey identified the actors involved in each agri-food chain: (a) research and development (R&D), technology transfer (TT), and financial support; (b) growers and their organizations; (c) collectors; (d) intermediaries such as transporters and primary and/or secondary middleman; (e) industries; (f) markets such as local markets, supermarkets, and retailers; (g) consumers; and (h) exporters (**figure 2**).

The main handling systems and agricultural practices were monitored in focal areas during harvests. Records were made in terms of productivity, economic factors, fruit varieties and their characteristics, packaging, and transportation from the field to areas of commercialization and industrialization. In addition, the global supply and demand for raw materials and derived products were analysed, using variables such as global production and consumption, and prices and their fluctuations. For these purpose a specific methodological tool was developed and is now used by all PAVUC partners.

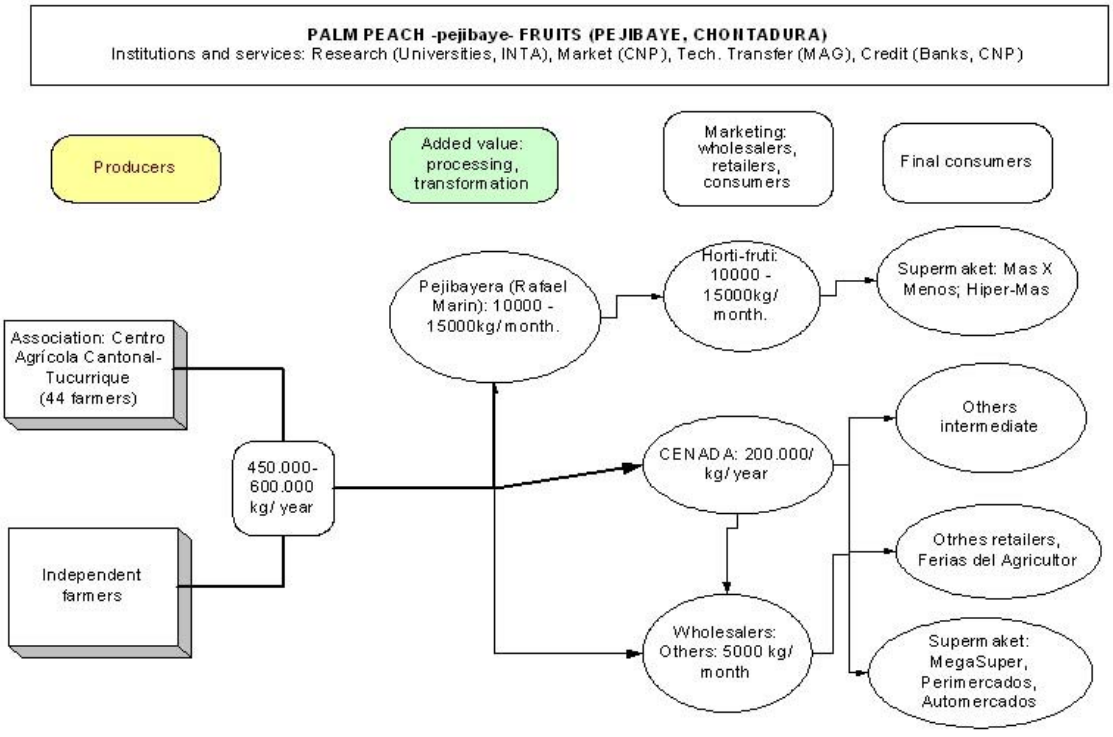


Fig 2. Example of the flow diagram of Peach Palm agricultural chain

In addition to the detailed characterization of the agri-food chains, innovations were also proposed to stakeholders—co-partners of the PAVUC project—through technico-socio-economic feasibility studies on the most promising products. Opportunities and constraints to the implementation of needed innovations have been identified and strong efforts made, using different communication tools, to increase dissemination of information among stakeholders. New business opportunities generated by the PAVUC project have emerged and are about to be realized. Two examples are the industrialization of tropical highland blackberry and açai-palm berry, both processed as food ingredients in health beverages in Europe.

Based on the composition of the nine fruits, new products have been developed but, first, the fate of relevant phytochemicals during conventional processing procedures was studied. For example, the impact of heat treatment on phenols, carotenoids, and vitamin C has been studied, demonstrating significant differences between food matrixes. For their larger scientific impact, results of these works have been disseminated as articles (*22-27*) or papers presented at international meetings.

From these results, some innovations have also been proposed to local industries that traditionally process fruits on a small scale. For example, removing oxygen sometimes significantly improves the preservation of phytochemicals of commercial interest (*22*, *28*). Yet, most extraction equipment used on small scale increases dissolved oxygen in juice, thus significantly lowering their overall quality. The PAVUC project has designed more adaptable equipment to allow juice extraction without introducing oxygen. Such equipment is easily constructed locally, and thus becomes readily accessible to small-scale fruit-juice processors. Use of enzymes, which considerably improves the extraction of most phytochemicals in juices (*28*, *29*) has also been enhanced at a small-scale level.

As well as improving conventional processes, considerable work has been carried out to develop innovative and appropriate processes for the secondary transformation of fruits in local industries. The results of the survey on agri-food chains showed that the procedures for adding value to underutilized food crops cannot be performed exclusively near production areas but that a secondary processing step is often required.

Membrane processes, although they can be implemented on a small scale, show considerable potential for endowing high added value to products. Cross-flow microfiltration was applied to almost all fruit juices, giving rise to stabilized clear juices of high microbiological, sensorial, nutritional, and functional quality with expanded marketing opportunities (*25*, *30-33*). Cross-flow microfiltration preserves most phytochemicals in the clarified juice, except carotenoids, and can be concentrated within the retentate, giving rise to new possibilities of producing high added-value by-products (*25* , *30*, *34*). Of the major innovative processes developed, this one showed perhaps the highest potential for industrial application, both in medium- and small-scale processing plants (*35*) **(figure 3)**. Industrial development is therefore under way, specifically for tropical highland blackberry juice.

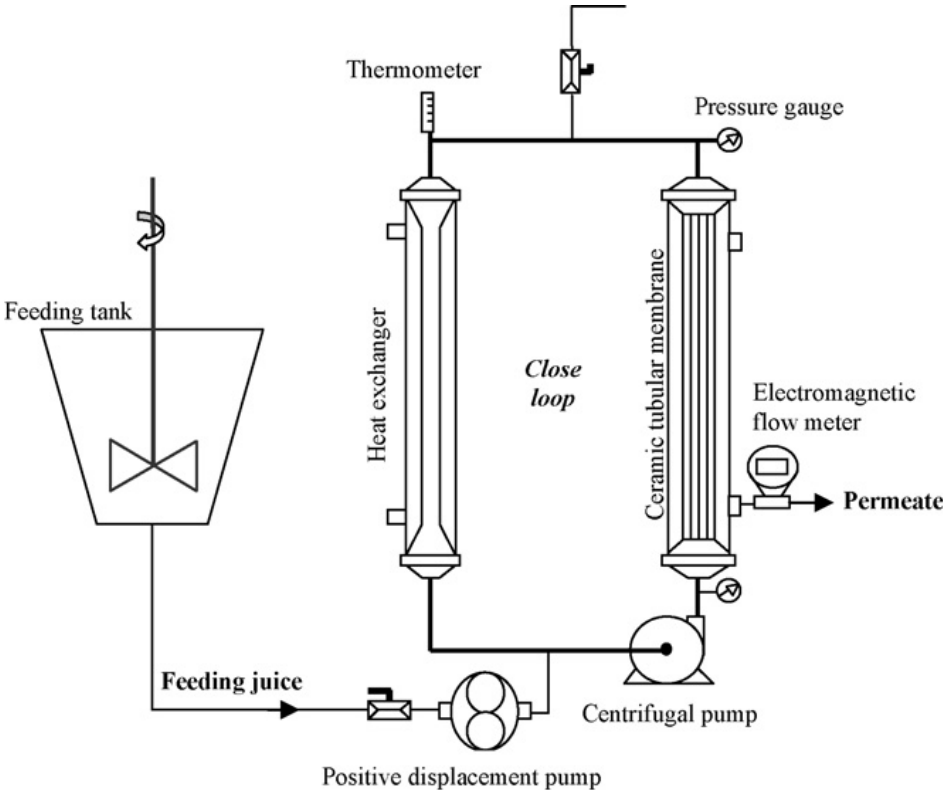


Fig 3. Schematic diagram of processing unit used in microfiltration

Other innovative procedures for processing fruit juices were also implemented on a pilot scale. For example, ultrafiltration, fine ultrafiltration, and nanofiltration were used to separate phytochemicals and obtain different fractions with high potential added value (*30*). A European patent is now being taken out on the coupling of membrane processes such as cross-flow microfiltration with fine ultrafiltration and nanofiltration.

Concentration by reverse osmosis was also applied to some thermosensitive juices (*31*, *32*, *36*). Even though permeate flows are often too low, reverse osmosis remains a good alternative for the better preservation of concentrate quality.

Other processes such as the use of resins to isolate and purify bioactive molecules were also implemented (*37*), but their potential for industrial application was less than that of the membrane technologies. The potential of spray drying to obtain fruit powders has also been assessed (*38*).

Considerable progress has been also made to process fruits into products other than juices. Deep-fat frying, coupled with a previous drying process such as osmotic dehydration or air drying, produces healthy snacks with a high content of bioactive molecules **(Figure 4)**. A comprehensive study on the fate of phenolic compounds during high temperature treatment was also implemented and, for the first time, kinetic behaviour of destruction was characterized. Findings may allow future optimization of processing parameters that involve temperatures of more than 100 °C (*23*, *39*, *40*).

Fig.4 tree tomato chips developed using vacuum frying.

For every process studied, the effects of processing parameters were optimized, taking into account not only quality but also economic considerations. Results were used to set up the technico-economic feasibility studies. Finally, samples were produced on a pilot scale to feed market studies at a local level and, for the most promising products, at an international level, more specifically in some Western European countries.
A full market study in Belgium was performed on eight products—six juices, one jam, and one snack—that is, juices of (a) açai-palm berry and (b) cashew apple, both from Brazil; (c) tropical highland blackberry juice from Costa Rica; juices of (d) naranjilla, (e) tree tomato, and (f) tropical highland blackberry, all from Ecuador; (g) berrycactus jam from Mexico; and (h) peach-palm snacks from Costa Rica.

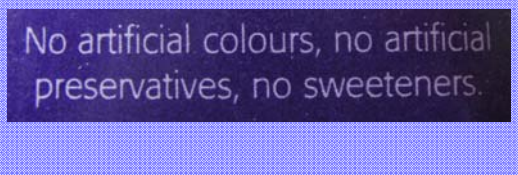
Studies first focused on the European market environment for unknown tropical fruit species. Emphasis was given to (a) obtaining insights on the perceptions and consumption behaviour of Belgian consumers towards tropical fruits and derived products (with a focus on juices) that are not yet common on European markets **(figure 5)**; and (b) analysing the Western European (i.e., Belgian) market environment for innovative tropical fruit juices. Focus group discussions were set up to understand consumers' perceived motives and the constraints to purchasing and consuming fresh tropical fruits and tropical fruit juices.

Fig 5 Belgian participants carrying out tests on the perceptions and consumption behaviour towards tropical fruits and derived products

The study resulted in recommendations for successfully positioning and selling novel tropical fruit products on the European market (*41*). For instance, overall, consumers have a positive attitude towards unknown tropical fruits. They believe that these fruits are potentially nutritious, healthy, flavoursome, attractive, and distinctive (*42*). Even so, some constraints exist for tropical fruit consumption. The main ones are the acquisition prices are perceived as high, unfamiliarity with the novel fruits, and possible sensorial repulsion (*43-45*). Consumers, therefore, prefer juices containing a mixture of unknown and known tropical fruits, whereas they find as too risky the purchase of juices containing only unknown tropical fruit juices (*42*). It was also shown that specific nutrition and health claims do not change this attitude (*46*). Although consumer awareness for health issues is increasing, nutritional and health claims alone are not sufficiently persuasive to induce the purchase of a novel product. The study confirmed that the only way to introduce a new tropical fruit juice is as an ingredient, mixed with already well-known fruit juices. This strategy is, in fact, being followed by most European food and beverage industries, which are making greater use of novel tropical fruits

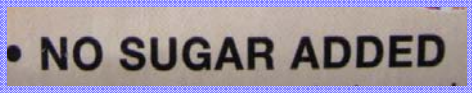
as ingredients to diversify their food products and beverages, and, eventually, enhance their health claims.

The study also showed that consumers prefer claims that emphasize the juices' naturalness (e.g., no colorants or containing natural fibres) over claims that possess a less natural link with the carrier (e.g., calcium enriched). Furthermore, results indicate that the relevance of the claim for consumers play an important role in their purchasing behaviour. Consumers with health-related needs (e.g., diabetics) tend to buy fruit juices with claims relating to their needs (e.g., no added sugar) **(figure 6)**. Some European fruit beverage industries have taken advantage of the insights obtained from the present work to design and develop juice mixes, focusing on developing product formulae that increase the product's health-related benefits without jeopardizing its sensory acceptability (*46*).



"These claims stress the naturalness of the juices.

"I do not associate calcium with tropical fruits but rather with dairy products, whereas you get vitamin D from the sun! It is strange to see this kind of information mentioned on tropical fruit juices."



"My husband is diabetic. If I buy tropical fruit juices, I have to be aware that no sugars are added".

Fig. 6 Opinions of consumers to claims on labels of tropical fruit juices

Different studies conducted by PAVUC projects have also determined the level of acceptability of biodiverse fruit juices. For instance, based on taste, consumers will accept a beverage containing less than 4–5% açai-berry juice (*47*) **(figure 7)**. In contrast, they accept a beverage containing tropical highland blackberry juice at considerably higher percentages.

Fig.7 Six fruit juices with açaí concentration varying from 4 to 40%

Based on collected information, preliminary market studies for some products developed by the project have been implemented. Nonetheless, a global analysis confirms that biodiverse fruits should be first processed in the producing countries and then offered as ingredients to European industries. Consequently, the market environment in Europe was studied for five promising tropical fruit juices (*41*) that could be used as ingredients (i.e., açai berry, cashew apple, naranjilla, tree tomato, and tropical highland blackberry).

A SWOT analysis was conducted to map the inherent strengths and weaknesses of the five production-and-supply chains and to evaluate the external market environment (opportunities and threats). Subsequently, the identified strengths, weaknesses, opportunities, and threats were entered into a SWOT matrix to identify key attention points for strategic development related to the fruits' use and expansion in Western European fruit juice markets (*48*) **(figure 8)**.

		Opportunities			Threats		
		Consumers' search for natural, healthy and nutritious fruit juices	Need for health-oriented innovation by the beverage industry	Consumers' interest in ethnic foods	Unfamiliarity with tropical fruits and their flavours	Credibility of nutrition and health claims	European market access requirements
Strengths	Fruits' nutritional value	a	a		b	b	
	Fruits' tropical origin	a	a	a	b		
	Well-established regional and national markets			a			b
	Existence of national processing industries		a				b
Weaknesses	Irregular and insufficient fruit supply	c	c				
	Inconsistent fruit quality	c	c				d
	Lack of advanced knowledge about production, transportation and processing issues, and product-related knowledge	c	c			d	d

Note: a, b, c, d signal the potential match between internal and external factors in the marketing environment: a=this strength can allow to benefit from this opportunity; b=this strength allows to cope with this threat; c=this weakness prevents from benefitting from this opportunity; d=this weakness prevents from coping with this threat

Fig.8 SWOT-matrix regarding the use of promising tropical fruit species and their potential in the West European fruit juice industry

As with all information generated by the PAVUC project, results were widely disseminated at different levels, starting from meetings or workshops with selected stakeholders, media briefings, flyers, oral presentations at national or international meetings, and scientific papers. The project's website (www.pavuc.soton.uk) makes detailed information of this executive summary available to a wider audience. The website itself will be maintained for at least 2 years after the project's end.

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2. DISSEMINATION AND USE

At the moment, only one products is ready to publicise even though others are underway.

The product is "microfiltrated tropical highland blackberry juice". The juice is free of microorganisms but has not been treated thermally. It preserves all the compounds of the original juice and contains 2 to 3 fold more soluble ellagitanins than competitors (ej. pomegranate juice).

Possible market applications (sectors, type of use ..) or how they might be used in further research (including expected timings). **Food industries**

• Stage of development (laboratory prototype, demonstrator, industrial product...): **Industrial product**

• Collaboration sought or offered (manufacturing agreement, financial support or investment, information exchange, training, consultancy, other): **Marketing**

• Collaborator details (type of partner sought and task to be performed): **Selling the product in Europe**

• Intellectual property rights ***granted*** or published: **Processing technology is protected by a non disclosure agreement.**

• Contact details involved: Consortium **CoopeAgrimar, Aprocam, Agrisal (Costa Rica)**

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:, Gerente General