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ORIGINAL PAPER

An attempt to recover economic losses from decadal changes in two lagoon systems of Sri Lanka through a newly patented mangrove product

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Abstract Kahandamodara and Kalametiya are two estuarine lagoons located within about 12 km distance along the Southern coast of Sri Lanka. According to a socio-economic survey, both lagoons have been moderately to high saline water bodies and the latter was an important center of prawn fishery until the late 1960s. Two irrigation projects upstream (Udawalawe irrigation scheme and Muruthawela Wewa), which came into operation in 1967 and 1968 respectively, increased freshwater inflows to these two lagoons and altered flora, fauna, and water quality, with a decline of lagoon fishery as a result. At the same time, the increase in freshwater favorised the Mangrove Apple *Sonneratia caseolaris* to expand spontaneously. Following many hectares of vegetation increase of this species, our study focused on recovering the economic loss of fisheries decline by using new ethnobotanic information on this species. We found that the pulp of the fruit of the Mangrove Apple is tasty and can be used to prepare a fruit drink. However, it has not been commercialised, or even practiced widely at homes, due to the fact that numerous small seeds in the fruit release certain phenolic compounds when damaged, giving a bad colour and an astringent taste to the pulp. We developed a method to get the fruit pulp from the Mangrove Apple minimising the addition of phenolic compounds. This fruit pulp was then used to produce ice cream and fruit drinks, and the whole procedure has been patented in Sri Lanka for the favour of the local people. Apparently this is a novel mangrove product reported for the first time in mangrove ethnobotany. In addition, analysis of the fruit pulp of the *S. caseolaris* for nutritional composition revealed that it is very rich in phosphorus and dietary fiber, indicating that these new products may have an even higher potential as a supplementary food. Its use as a health food and as a commercialised eco-product is expected to bring

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new gains in spite of the former ecosystem and fishery decrease. It is however not known to which extent these novel ethnobiological/socio-economical uses outbalance functions lost by ecosystem degradation.

Keywords *Sonneratia caseolaris* · Spatio-temporal change · Nutrition · Dietary fiber · Sri Lanka

Introduction

Decreases in mangrove areas due to anthropogenic activities are common in the tropical and subtropical world (Alongi, 2002; Farnsworth & Ellison, 1997). Nevertheless an increase of the mangrove cover in two closely located lagoons in Sri Lanka was reported recently. In Kalametiya lagoon, the mangrove cover has been increased by 550% over a period of 38 years spanning from 1956 to 1994 (Jayatissa et al., 2002b). A similar, but less severe, increase (24%) has also been reported in the mangrove of Kahandamodara lagoon (Sooriyarachchi, 2004). These two lagoons are in the southern coast of Sri Lanka within a distance of 12 km. The cause of the increase in mangrove cover has been traced to the increased freshwater influx as a result of upstream irrigation works (Dahdouh-Guebas et al., 2005b).

Studies by Jayatissa et al. (2002b), Sooriyaarachchci (2004) and Dahdouh-Guebas et al. (2005b) on the changes in cover of different plant species or species assemblages (incl. mangroves) by using remote sensing and geographic information systems (GIS) reveal that the area covered by the low saline mangrove *Sonneratia caseolaris* (L.) Engler had increased dramatically in both lagoons. In Kalametiya, the increase went from 4.5 to 139 ha over a 38 year period. The floristic changes suggested a transition of the mangrove environment from saline to low saline conditions as a result of increased freshwater flow (Dahdouh-Guebas et al., 2005b). The freshwater inflows of these two lagoons have increased since the 1960s, with the commencement of two irrigation projects upstream (Udawalawe irrigation scheme and Muruthawela Wewa), which came into operation in 1967 and 1968 respectively. The larger of the two, i.e. Udawalawe reservoir, that was built by damming the fourth largest river of Sri Lanka, which supplies irrigation water for paddy fields on catchments of the two lagoons. The excess of irrigation water flows to these lagoons before discharging into the Indian Ocean. The increased freshwater inflows to these two lagoons altered flora, fauna, and water quality, resulting in a decline of lagoon fishery. In the absence of water quality data for the period prior to 1956, the authors conducted questionnaire surveys and hydrological calculations which proved that the salinity had been higher before the upstream irrigation works started (Dahdouh-Guebas et al., 2005b). The same surveys also revealed a decrease in fisher family demography. It was clear that Kalametiya had been a very important fishery center particularly known for its high shrimp catches. Kahandamodara, although never a significant fishery center, is likewise unable to support number of fisherfolk families similar to the number that existed prior to the changes.

In general, the population density and poverty of the people living around mangroves are higher. Under these circumstances, the loss of livelihood earned from the lagoon fishery is detrimental for the natural resources (including mangroves) of the area, as poor people may exploit mangroves if there is any possibility to earn

money through those resources. In addition, degradation of mangroves has also been found to have played a role in the ability of these forests to act as a living dyke during the tsunami disaster of December, 26, 2004 (Dahdouh-Guebas et al., 2005c). Both the dependency of the lagoon dwellers on fisheries, as well as the dependence of the coastal area on mangroves for physical protection against ocean influences is valid for the lagoons under study here. It is necessary to introduce alternative incomes, which do not damage the environment or the natural resources. It is much better if such alternatives are based on sustainable uses of mangroves or of the lagoon, because dwellers who get benefits from such projects will be encouraged to protect that resource. The true mangrove *S. caseolaris*, which is one of the co-dominant species in Kahandamodara (Sooriyarachchi, 2004) and the most dominant species in Kalametiya (Jayatissa et al., 2002b), appears to be a good candidate to use in such an attempt. Its ripe fruits are used to prepare a tasty food drink, particularly in coastal areas of Sri Lanka, but its preparation was limited to domestic level and never been commercialised. Therefore the objective of this study was to develop food products which can be commercialised, using *S. caseolaris* in a sustainable way, in order to give a financial benefit to the dwellers.

Materials and methods

Questionnaire-based survey on commercial uses of *S. caseolaris*

A simple questionnaire was used to obtain information on economic uses of *S. caseolaris*. Out of the local residents and mangrove uses of each lagoon, 25–30 families living adjacent to each mangrove forest were selected to collect information. The head or the most senior member of each family was questioned to get their response on the following:

1. Period of living in association with lagoon
2. Occupation
3. Uses of *S. caseolaris* and frequency of use
4. Possibility of earning money from products of *S. caseolaris*

These questions were asked to gather information on the feasibility of maximising the use of *S. caseolaris* in a sustainable way giving a financial benefit to the dwellers.

Development of food products from mangrove apple fruits

Non-scholarly reports state that some local industries who produce and sell fruit drinks from common fruits had tried to produce and commercialise fruit drinks from *S. caseolaris* also, but failed. Therefore, impediments for the production and commercialisation of food products from *S. caseolaris* fruits were studied by checking the shelf life of fruit drinks prepared according to:

(a) the traditional method practiced at domestic level;
(b) a common industrial method used to prepare other common fruit drinks; and
(c) methods which were planned to overcome the problems encountered in (a) and (b).

For the preparation of the fruit drink from *S. caseolaris* according to the traditional method practiced at domestic level, ripe fruits were washed and their persistent calyx were removed. Then fruits were crushed and thoroughly mixed with enough water to get a homogenous mixture. It was then filtered through a filter with a suitable mesh size to remove seeds and skin parts. The filtrate was mixed with sugar to obtain the fruit drink. Two sets of samples of the prepared drink, one in closed containers and the other in open containers were kept under the room temperature and checked after 12 and 24 h for their colour, taste, and texture.

In the normal industrial method, fruits are blended to obtain a homogenous fruit pulp and used in the preparation of fruit drinks. But this method could not be applied for fruits of *S. caseolaris* as the fruit contain large number of small seeds embedded in the edible part and damaged seeds accelerate the browning of the pulp resulting in a strong astringent taste. Therefore the fruit drink prepared according to the above traditional way that is practiced at domestic level, was used to prepare a bottled fruit drink and check the shelf time. In that process the fruit drink was preserved with Sodium benzoate (11.0 mg l^{-1}) and Sodium metabisulphate (4.0 g l^{-1}), 190 ml aliquots were taken into 200 ml bottles and then sealed before pasteurisation at 85°C. These samples were also checked once every two months as above for their colour, taste, and texture.

As the enzymatic browning of the fruit pulp was encountered as a major impediment in commercialisation of fruit products, an attempt was made to prevent the browning. The rate of enzymatic browning in fruit products depends on the concentration of oxygen and the enzyme polyphenoloxydase (Miller, 1998). Therefore, a method was developed to get the fruit pulp under low temperature in order to reduce the rate of enzyme reaction and further measures were taken to prevent exposure to oxygen (this improved method is described in the results section).

Because it was reported that the commercial value of *S. caseolaris* fruit is reduced due to infestation by a fruit fly, three random samples of fruits with 10 fruits in each, from both mangroves (i.e. Kahandamodara and Kalametiya) as well as from five other mangrove areas (i.e. Matara, Galle, Ambalangoda, Alutgama and Moratuwa) in which *S. caseolaris* is abundant, were taken and checked for pest attacks.

Nutritional composition of *S. caseolaris* fruits

The fleshy mesocarp that is the edible part of *S. caseolaris* fruits, separated from seeds and the outer skin was analysed for its nutritional composition. Proteins, lipids, different carbohydrates, vitamin C and some important minerals in this edible part were quantified according to methods specified in AOAC (1997).

Results

More than 50% of the respondents in each lagoon were engaged in fishery or agriculture as the major occupation. However, almost all the people in these two categories were engaged in an additional occupation due to the low income of the main occupation, and due to its seasonal nature. In some families women were engaged in income generating activities, as the income earned by the head of the

Fig. 1 Sri Lankan lady selling *Sonneratia caseolaris* fruits along a sidewalk in the centre of Galle (SW coast). Fruits are sold for a price as low as 2–3 LKR per fruit

family was not enough even for the basic needs of the family. One of these activities was the selling of *S. caseolaris* fruits on the market (Fig. 1).

According to the respondents the wood of *S. caseolaris* was not a good quality firewood, and therefore it was used only when there was no other firewood alternative. The wood did also not classify as good quality timber, and was used for temporary structures only. Pneumatophores of *S. caseolaris* were used to make floaters for fishing gear and bottle stoppers but not on a commercial scale. Juice extracted from crushed raw fruits were used as first aid for bleeding piles. Ripe fruits of this species are used to make a fruit drink at domestic level. However respondents revealed that its commercial value is very low as ripe fruits perished quickly and fruits in populations of some areas are infested with insect larvae. Verification of this infestation in our study revealed that 35–60% of the fruits collected from the mangrove communities at Matara, Galle, Ambalangoda, Alutgama and Mortatuwa were indeed infested with the a larval stage of an as yet unidentified moth. However, all the samples of fruits collected from the two study sites, Kahandamodara and Kalametiya, were free from pest attacks and those fruits were used for the preparation of food products and nutritional analysis of the fruit pulp.

The fruit drink prepared according to the traditional method practiced at domestic level, becomes unpalatable within 24 h from the preparation due to fermentation and browning with the development of an astringent taste. Bottled fruit drink prepared according to the normal industrial method also turned to a brown

colour, but at a lower speed. However the taste or texture of the drink did not change, and the drink remained palatable for more than 6 months.

As the browning process is faster when the fruit pulp or fruit drink is kept open, it appears to be an enzymatic browning resulted by the action of polyphenoloxydase on phenolic compounds in the presence of oxygen.

The improved method to prepare the fruit pulp minimised the browning and the development of an astringent taste. The process started with partly ripened fruits (usually fruits are in this stage when they shed from the trees under natural conditions). The fruits were washed thoroughly and left for about 12 h at the room temperature to allow further ripening. Then the persistent calyx of the fruits were removed and the fruits were frozen. Frozen fruits were used after thawing for the preparation of the fruit pulp. Freeze thawing makes it easier to remove the outer skin of fruits and it also makes the mesocarp softer, facilitating the preparation of a pulp easy and fast without crushing hard. Freeze-thawed fruits (without the outer skin and the calyx) were mixed with water in 1:1 proportion (by weight) and then stirred using a blunt plastic stirrer to get a creamy mixture. More water can be added at this stage, depending on the desired type of final food product. The removal of seeds from this mixture can be done in two ways. In small-scale productions, the mixture can be taken to a plastic mesh (with the mesh size of 2.5 mm) and stirred gently to collect the pulp that is thick and creamy. In large-scale productions, the principle of centrifugation can be applied to separate seeds and the pulp. Then the fruit pulp can be stored frozen or used immediately in preparation of food products. The whole procedure is completed within a short period to minimise the rising of temperature and hence enzymatic browning.

About 1 l of the fruit pulp (including 50% of added water) can be obtained from 1.0 kg of freeze-thawed fruits. This thick and creamy pulp can be used to prepare two food products : concentrated fruit juice and ice cream. The fruit pulp was diluted in 1:2 proportion with a saturated sugar solution and preservatives (i.e. sodium benzoate and sodium metabisulfite) were added in recommended concentrations to prepare 'concentrated mangrove apple juice'. The fruit pulp was used to prepare ice cream of which 25% (by volume) is the fruit pulp free from any artificial ingredients. The shelf life of ice cream and concentrated mangrove apple juice was more than 6 months. This whole procedure is now patented (Patent no.13150) under the Code of Intellectual Property Act no. 52 of 1979 in Sri Lanka (Fig. 2).

The analysis of the fruit pulp for the nutritional composition revealed that the fruit pulp is remarkably rich in dietary fiber, calcium and phosphorus. Quantities of some of the important nutritional components in the edible part of *S. caseolaris* fruits are given in the Table 1.

Discussion

Except products from the phloem sap of *Nypa fruticans*, foods and beverages obtained directly from mangrove plants in the world, are few (Bandaranayake, 1998; Hamilton & Snedaker, 1984; Saenger et al., 1983). Exploitation of mangrove wood for commercial purposes is not recommended for a country like Sri Lanka as the total coverage of mangroves in the country, does not exceed 120 km^2. Hence, only lagoon fisheries can be practiced in a sustainable way to earn money from mangrove

Fig. 2 Mangrove apple juice bottled and commercialised in collaboration with the Small Fishers Federation of Lanka (SFFL)

Table 1 Mean quantities of some common nutritional factors in the edible part of *Sonneratia caseolaris* fruits

Component	Content (g/100 g fresh weight of edible part)
Moisture	76.0
Protein	2.10
Fat	1.95
Carbohydrates	
Reducing sugars	4.38
Non-reducing sugars	0.48
Dietary fiber—soluble	5.40
Dietary fiber—insoluble	6.00
Other carbohydrates	3.24
Phosphorus	0.141
Iron	0.001
Calcium	0.027
Vitamin C	0.018

ecosystems. Under these circumstances, the loss of income from the lagoon fishery for dwellers may be detrimental for the natural resources of the area including mangroves, as poor and desperate people may use them in a destructive manner, for instance for land reclamation for aquaculture (Dahdouh-Guebas et al., 2002). Therefore it is worthwhile to explore the possibilities to use mangroves in a sustainable way to earn some money for mangrove dwellers. Such attempts are very important for the dwellers around two estuarine lagoons, Kahandamodara and

Kalametiya, who lost their livelihood at least partly due to the collapse of lagoon fishery by changes which were created as a result of upstream irrigation projects. The true mangrove, *S. caseolaris*, that is one of the co-dominant species in Kahandamodara (Sooriyarachchi, 2004) and the most dominant species in Kalametiya (Jayatissa et al., 2002b) appears to be the only candidate to use in such measures.

Three species of *Sonneratia* ('*Kirala*' in Sinhala and 'Mangrove apple' in English), are recorded in Sri Lanka. *S. alba* and *S. apetala* are reported in Sri Lanka as rare and very rare species respectively, but *S. caseolaris* is a common mangrove element in low saline estuarine habitats, particularly in southern and western coasts (Jayatissa et al., 2002a; Macnae & Fosberg, 1981). In addition to the occurrence in mixed mangroves, this species is growing as monocultures in large areas of some estuaries e.g. Ambalantota and Kalametiya (Jayatissa et al., 2002a, b).

Fruits or other parts of the former two species are not eaten or used as a component in preparation of any food, but ripe fruits of *S. caseolaris* are edible and used to prepare a fruit drink manually in Sri Lanka. This use is mainly restricted to domestic level, even in coastal areas where this mangrove species occur. No food product from *S. caseolaris* has been commercialised in Sri Lanka so far, probably due to the following impediments in commercialising such a product:

(a) Fruits of *S. caseolaris* in some areas are infected with a larval stage of an insect without any visual sign from outside and hence there is no method for pre-selection of pest free fruits;
(b) The outer skin of the fruit should be peeled off manually in preparation of a pulp or extraction of fruits and it is highly labor-consuming task;
(c) Ripe fruits cannot be store under room temperature more than a day as they perish rapidly;
(d) Each fruit contains a large number of small seeds embedded in the fleshy part of the fruit. Mechanical crushing with hard objects or blending ripe fruits damage seeds resulting a bitter taste and a discolouration of the pulp;
(e) Browning with a development of an astringent taste, takes place within 12 hours in the fruit pulp prepared according to the conventional way, and it appears to be an enzymatic browning. Mechanical crushing or blending the fruits accelerates the browning.

These problems have been resolved in this new procedure as follows.

Ecological survey carried out recently revealed that the infestation of fruits of mangrove apple is not a common phenomenon for all the populations. It is observed that fruits of the two populations of *S. caseolaris* at Kalametiya and Kahandamodara are free from pests. The area covered by *S. caseolaris* in these two lagoons is about 150 ha and usually flowering takes place twice a year giving a harvest enough to process carryon a medium scale food industry based on their fruits. The life cycle of the insect pest in relation to the phenology of *S. caseolaris* will be studied with the aim to control the infestation in *S. caseolaris* in other areas.

Freeze thawing of ripe fruits, an important innovation in the improved methodology for the extraction of the fruit pulp reported here, makes it easy to remove the outer skin and obtain the pulp without damaging seeds as it makes softer the fleshy mesocarp. It reduces the browning and the development of the astringent taste, and it counters *S. caseolaris*' reputation as easily perishable fruits. Browning of the fruit pulp in the product of 'concentrated fruit juice' is ceased as the higher sugar

Table 2 Comparison of soluble dietary fiber (SDF), insoluble dietary fiber (IDF), Phosphorus (P) and calcium (Ca) contents in fruits of *Sonneratia caseolaris* with those in many other fruits and foods

Work/References	Number of foods/fruits analysed	Number of fruits/foods showed higher amount of each component, compared to *S. caseolaris* fruits			
		SDF	IDF	P	Ca
Li, Andrews, and Pehrsson (2002)	70	0	3	–	–
Ramulu and Rao (2003)	25	0	3	–	–
Sanchez-Castillo et al. (1998)	35	–	–	0	14
Englberger et al. (2003)	4	–	–	0	3

concentration excludes oxygen (Miller, 1998). Low temperature may be the reason for the prevention of browning in ice cream.

The analysis of the fruit pulp of *S. caseolaris* extracted by the improved method revealed that the fruit pulp of *S. caseolaris* is very rich in dietary fiber (11.4/100 g), and two minerals: Ca (0.027/100 g) and P (0.141/100 g). The contents of soluble and insoluble dietary fiber and the two minerals, Ca and P, in many other fruits are compared with those in fruits of *S. caseolaris* in Table 2. It reveals that fruits of *S. caseolaris* could be among the fruits with the highest contents of these nutritional factors. It is reported that leaves and fruits of *S. caseolaris* may be eaten raw or cooked by people in some countries (Bandaranayake, 1998; Hamilton & Snedaker, 1984; Saenger et al., 1983). But this could be the first attempt to use 'mangrove apple' fruits as a component in the preparation of supplementary food that can be commercialised. Fruits of *S. caseolaris* are occasionally sold in local fairs at a current rate of 15–20 LKR kg^{-1} (Fig. 1) (1€ = 125 LKR in Sept. 2005; LKR is the international abbreviation for 'Sri Lankan Rupees'). But the same amount can be used to prepare 1 l of concentrated fruit juice that is worth about 200 LKR in the local market. Even though 40 LKR is paid for 1 kg of fruits, total cost of production may not exceed 100 LKR per 1 l of concentrated fruit juice. Although statistics on the production of fruits of *S. caseolaris* in Sri Lanka is not available at the moment, visual observations show that a single tree produce plenty of fruits twice a year and even in the low production season it is possible to get some harvest. Preliminary investigation revealed that about 25 kg of ripe fruits can be collected from 1 ha of Kalametiya mangrove forest within a day at the peak of the fruiting season. However, a proper phonological survey should be carried out to know the correct figures of annual production. As the extent of the cover of *S. caseolaris* population in Kahandamodara and Kalametiya is about 150 ha and fruits are free from the pest attack, these two mangrove forests could be used as a resource for a medium scale food industry giving a compensation for the dwellers who lost their livelihood due the collapse of fishery.

If the above protocol is commercialised in a proper way, mangrove dwellers will be able to collect fruits of *S. caseolaris* and sell to the manufacturers of the product. Unlike for other crops, there will not be a maintenance cost as lagoons and estuaries receive more than enough nutrients with the runoff.

The importance of these food products may not be restricted to the two relevant lagoons. This newly patented protocol may have a high potential as an eco-product that could lead to the conservation and management of mangroves in the world as

well as in Sri Lanka. Although mangrove ecosystems provide outstanding economic uses and invaluable ecological services, they are still decreasing in surface around the world (Kathiresan & Bingham, 2001) and ranked among the most threatened of coastal habitats, particularly those in developing countries in tropical regions (Saenger et al., 1983). Also in Sri Lanka, mangroves are one of the most misused and threatened coastal eco-systems, and recurrently scientists emphasise the need for mangrove conservation (Dahdouh-Guebas et al., 2002, 2005c) and for early detection of its degradation (Dahdouh-Guebas et al., 2005a; Dahdouh-Guebas et al., 2005b). This situation is aggravated by the fact that a considerable portion of the country's mangrove lands are privately owned properties (IUCN, 1996, 2000). Hence, destructions of such mangroves are taking place without control. Although there are some rules and regulations aimed to protect mangroves, they are undermined by the people with a business interests and political patronage (Foell, Harrison, & Stirrat, 1999). Therefore a motivation of dwellers to protect mangroves through a creation of direct livelihood from mangrove forests could be the most effective way of protecting mangroves in Sri Lanka. Then, people may be actively involved to protect the mangrove forest as they know their livelihood merely depends on the well-being of the mangrove ecosystem, and as a population their voice could not be undermined by political patronage or other hidden forces. Although the economic utility of fruits could be considered as a basis of propagation of *S. caseolaris*, its distribution will not be extended to all mangroves, as the species is successful only in low saline habitats (Jayatissa et al., 2002a). Therefore, the economic utility of fruits may help to conserve *S. caseolaris* where they are now. Actually the destruction of part of the Kalametiya mangrove forest by a fire that was set by paddy farmers during the dry spell in 2001, probably to clear densely grown cattail population between the mangrove forest and paddy lands, motivated authors to find an economic use from the Kalametiya mangrove which is dominated by *S. caseolaris*. That fire slowly spread within the forest for more than a week burning even thousands of bird nests, until it stopped naturally. No any attempt was made by the general public, authorities or any other organisation to stop the fire in advance. But if there was an economic use from the mangrove forests for the dwellers, they would have attempted to stop the fire. This annecdotical illustration indicates that if food products from *S. caseolaris* were improved and the industry extended to give an economic benefit to the dwellers, it may serve as a motivation to protect the mangrove forest.

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