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Utilization of Renewable Energy Sources for Drying Medicinal and Nutritional Plants in Panama

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Abstract This research study looked at the design, construction, running and evaluation of an artisanal processing plant or factory that included a solar oven to capture the thermal energy for drying medicinal and nutritional plants. The use of renewable resources, especially solar energy plus a minimum of technological equipment and attention to principles of quality, hygiene, and future sustainability, contributed to the success of this engineering project. The factory was located in the rural community of El Cacao, District of Capira, Province of Panama, Republic of Panama, Central America. An indirect solar oven represented the center of the operation of the factory. Tests with locally grown plants including oregano (Origanum vulgare), coriander (Coriandrum sativum), rosemary (Rosmarinus officinalis), balsamino or bitter melon (Momordica charantia) and lemongrass (*Cymbopogon citrullus),* were conducted to measure the heat transfer and conductivity from the oven to the drying room. We also conducted an organoleptic study with community members to assess dried lemongrass *as tea vs. a commercial tea*. Preliminary tests with medicinal plants showed the efficiency of the factory in drying with significantly lower times than those found in the literature, obtaining the recommended humidity percentages. In addition, the organoleptic features of the lemongrass tea were rated as with more acceptable features as compared with the commercial lemongrass tea. The preliminary findings reported here are promising and, from the reception from community members, it is expected that they will accept the products being developed for them. The goal is for this and similar communities to have better and more permanent access to their traditional nutritional and medicinal plants.
Keywords *Drying Time; Humidity Rate; Organoleptic Characteristics; Solar Energy; Temperature Control*

1. Introduction

Since ancient times, man has learned to dehydrate and dry grains, fruits, meat and herbs to ensure the availability of food and medicinal products and thus to have them available all year and to survive in times of scarcity. There is a global movement towards the use of natural and healthy products, among which are medicinal plants used fresh or minimally processed, for example, dehydrated.

However, in developing countries such as Panama, artisanal simple technologies to facilitate the use of plants for nutritional and medicinal purposes are absent in most rural communities. However, in this country, the use of indigenous plants by rural communities is quite common but mainly used as fresh products. As an example, previous work by the authors of this paper revealed that in a rural community of Panama, approximately 150 local plants were identified as with high cultural value because of their medicinal and nutritional attributes, with most of those plants used as fresh herbs [1].

The study reported here was aimed at the planning, building and use of a small processing plant or factory. It included a solar oven that provided the energy needed for drying traditional plants in a rural region of the Republic of Panama. This Central American country has long periods of sunshine equivalent to a monthly average of 1,967 hours/sun and a daily average of 5.4 hours/sun [2].

The capacity of the factory for drying locally produced plants was tested with favorable results as reported in this paper. The results evidenced the potential for the use and application of renewable, low-cost technologies that can contribute to improving innovative production systems and economic capacity of rural populations.

2. Materials and Methods

2.1. Study Area

The rural factory for the artisanal processing and drying of medicinal and nutritional plants was built in the rural community of El Cacao, district of Capira, Province of Panama, Panama. El Cacao is a rural, traditional community where the use of locally grown plants, for nutritional and medicinal purposes, is still widely practiced by its inhabitants [1].

This community is located 75 kilometers from Panama City, capital of the Republic of Panama, at a height of 700 meters above sea level in the highlands near the Trinidad mountains, with Latitude: 8º, 77’ N and Longitude: 80º, 02’ W (Figure 1).

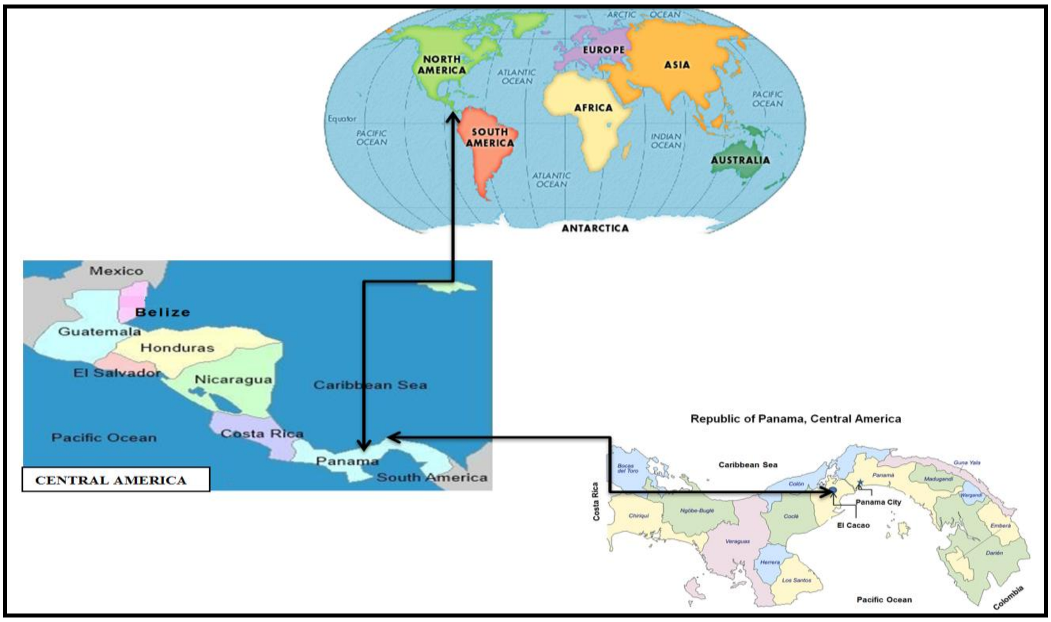

Figure 1: *Localization of the Republic of Panama and the Rural Area of El Cacao in the Globe*

2.2. Design and Construction of the Processing Factory

The land chosen for the project, a two-hectare farm in the community of El Cacao, met all the parameters needed for the building, including drinking water, soil quality, and sufficient rainwater from two creeks and a spring. Local authorities and community leaders gave their approval for this project, and several community members participated in the activities related to the construction of the processing factory and to the planting and harvesting of the plants to be dried at the factory.

An important component of the processing factory was a solar oven. Its construction required to meet the following conditions: dimensions, physical orientation according to the sun path, and conservation of the internal temperature in the processes, plus needed equipment and instrumental. The roof of the oven was built with a semicircle shape using transparent polyethylene sheets to achieve the free passage of the sunlight on the elements for the collection and convection of the heat energy from the sun. The oven floor was built with a concrete slab. Walls and floor were painted dark black to reduce reflection coefficient and increase the absorption coefficient.

2.3. Testing of the Heat Transfer in the Drying Chamber

Once the solar oven was in place, a series of measurements of the different temperatures at critical points of loss of heat transfer were done. These preliminary measurements were performed to find how the heat conduction process occurred, based on temperature gradients and the area to which the heat was transferred. These temperature measurements were aimed at the estimation of the free conduction of heat from the oven to the drying chamber.

2.4. Drying of Nutritional and Medicinal Plants

To test the capability of the processing factory, we conducted a series of tests with local plants to measure the parameters associated with the percentage of dehydration, changes in temperature, time spent in drying and conservation of organoleptic characteristics. For our tests, and based on the literature, we assumed that we started with a percentage of fresh humidity between 70-95% and aimed to reach a humidity of 30-10% dry moisture [3, 4].

For those tests, we used indigenous plants cultivated in a demonstration garden previously established in the premises of the factory. The first series of tests were done during the months of October and November of 2013, with 4.5 hr of solar radiation per day, as average. With oregano (*Origanum vulgare*), coriander (*Coriandrum sativum*), rosemary (*Rosmarinus officinalis)* and balsamino o bitter melon (*Momordica charantia*), which in Panama are commonly used plants as food or as traditional medicine [4, 5].

In December 2013, we continue with additional tests, including drying of lemongrass. The first experiment was to assess drying times. It was done with the leaves cut at different lengths (cm) and separated into four batches of 10 grams each. We processed another batch of lemongrass and packaged the dried leaves in tea bags of 5g, which were used for *an assessment of the organoleptic characteristics of this artisanal tea, as compared to a commercial lemongrass tea.*

*As evaluators, we recruited a group of 15 community residents, who were invited to participate in a tasting session of lemongrass tea. T*he group was asked to assess the sensory attributes of both types of tea with a questionnaire based on 5-item Likert scales. The assessed characteristics included aroma (1= very light, 5= very fragrant), taste (1=very bitter, 5=very sweet), and flavor (1=very mild, 5=very strong) plus overall acceptability, using 5-item Likert scales. We first asked panelists to rate their personal preferences for lemongrass tea (in general) regarding color, aroma and taste. Then we conducted the tasting session where panelists were asked to assess the sensory characteristics of the artisanal and commercial lemongrass teas, which were only identified as tea A and tea B.

3. Results

3.1. The Processing Factory and the Solar Oven

The physical plant was built as a linear building of 4m wide by 17mts long following standard specifications for ceilings, finishes, doors, and windows, plus the specifications in the electrical and plumbing plans. Under the roof, it was placed an insulating sheet to prevent radiation to the areas of production. The physical structure had a horizontal orientation from east to west, taking into account the azimuth, inclination, and orientation of the sun factor, where the sun rises and where it sets. The position of the building gave the orientation of the solar oven, and the photovoltaic solar panels were placed on the roof of the building.

3.2. Heat Transfer in the Drying Chamber

Temperature measurements were performed with a laser thermometer and taken at critical points at the exterior and interior walls of the drying chamber, in the month of October 2013. Seven measurements were registered at the following times: 8:00 am, 10:00 am, 12:00 m, 2:00 pm, 4:00 pm, 6:00 pm and 8:00 pm, with the results observed in Figure 2.

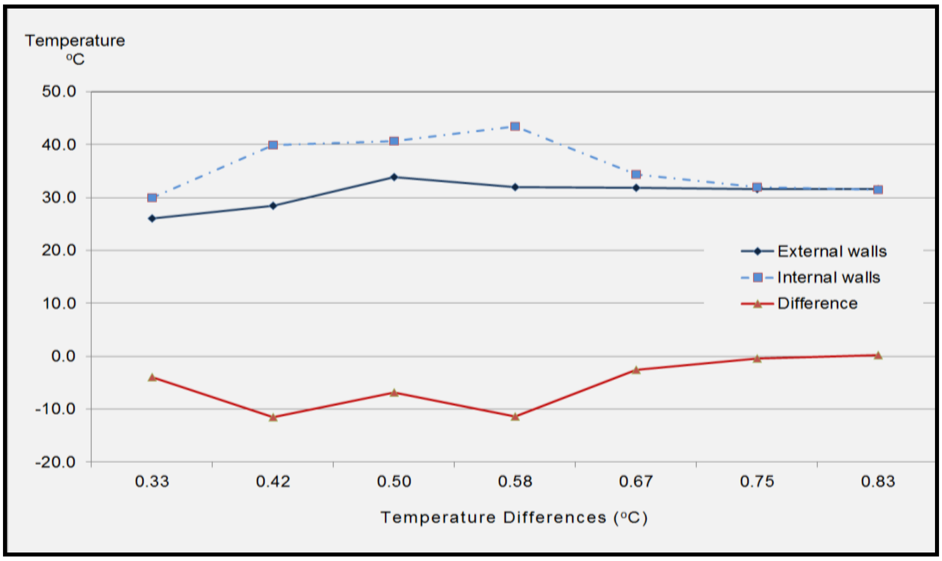

Figure 2: *Values of Critical Points in the Outer and Inner Walls of the Solar Oven*

3.3. Drying of Medicinal and Nutritional Plants

The selection of samples was rigorous, choosing healthy plants at the demonstration garden. Healthy leaves of bright color were selected. All plants were harvested in the early hours of the morning. For washing and cleaning they, clean water with about 10 mg/L of calcium hypochlorite was used. After washing, a manual pre-drying with clean towels was done.

The first round of preliminary drying tests was performed with four lefty plants: coriander, balsamino, rosemary, and oregano, also obtained the demonstration garden. With coriander leaves, two groups of different weights were tested. Average temperatures in the drying chamber were registered as well as the time needed to reach a moisture content ratio (MCR) expressed with the weight in grams as in percentages. The results of the drying of these four products are shown in Table 1. It can be seen that, in a relatively short time, the expected MCRs were reached. These times were shorter than the values recommended in the literature and those reported in traditional processes with drying with direct sunlight.

Table 1: *Results Obtained with Drying of Medicinal Plants during the Months of October and November 2013*

	Coriander (Batch 1)	Coriander (Batch 2)	Balsamino	Oregano	Rosemary
Average Temperature (°C)[1]	33.3	33.3	32.6	32.3	32.2
Drying time (h:min)	18:20	18:20	14:00	9:55	17:15
Yields					
Initial weight (g)	150	175	200	105	227
Dry weight (g)	40	31	78	37	68
MCR (g)	110	144	122	68	189
MCR (%)	73.3	82.3	61.1	64.8	83.2

[1]Recorded average temperature in the drying chamber

We continue with additional testing using another plant, lemongrass, which is commonly use in El Cacao, both as medicinal and as a nutritional herb. Fresh leaves were collected and cleaned as indicated before, and four batches of 10 g with leaves cut at different lengths. Each batch was subjected to the drying process for different periods of time to observe changes in color and aroma as drying continued, until obtaining an expected water loss of at least 60%. The batches were weighed at intervals of time at 1, 2, 3, 4 and 21 hours when dehydration, estimated as the MCR expressed in percentages, was achieved, as presented in Table 2. It was observed that, with the four sets of samples, the percentage of water loss (33%) was rapid and constant during the first 4 hours and then the drying process slowed as expected, with a further evaporation of 40% or more achieved in 17 additional hours.

Table 2: *Drying of Lemongrass with Leaves Cut at Different Lengths*

Batch Specification	Batch 1 Leaf ± 12 cm	Batch 2 Leaf ± 6 cm	Batch 3 Leaf ± 3 cm	Batch 4 Leaf ± 1 cm
Drying Time (hr)	(g)	(g)	(g)	(g)
0 hr	10.0	10.1	10.1	10.0
1 hr	7.0	6.8	8.1	7.2
2 hr	6.2	6.3	7.0	6.5
3 hr	5.7	6.0	6.9	5.5
4 hr	5.2	5.7	6.5	5.4
21 hr	2.9	2.8	2.9	2.6
%MCR (%)	71.0 %	71.7%	71.0 %	74.0 %

3.4. Assessment of the Acceptability of Artisanal Lemongrass Tea

To assess the acceptability of the artisanal lemongrass tea, we tested the perceptions of a group of community residents of El Cacao, which included 15 adults (9 men and six women), with ages between 23 – 56 years.

Those naïve panelists were first asked to rate their personal preferences for lemongrass tea, which are detailed in Table 3. We noted that the majority of panelists preferred a moderate color (not too light, not too dark); a strong aroma and a sweet or “just right” (not too sweet, not too bitter) taste.

Table 3: *Ratings of Desirable Organoleptic Characteristics in Lemongrass Tea by Community Evaluators*

Preferences	Ratings	
	N	%
Color		
1. Very light	1	6.7
2. Light	5	33.3
3. Moderate	8	53.3
4. Dark	1	6.7
5. Very dark	0	0.0
Aroma		
1. Very light	0	0.0
2. Faint	0	0.0
3. Moderate	4	26.7
4. Strong	8	53.3
5. Very fragrant	3	20.0
Taste		
1. Very bitter	0	0.0
2. Bitter	1	6.7
3. Just right	6	40.0
4. Sweet	8	53.3
5. Very sweet	0	0.0

Blind assessment of the flavor and taste of the artisanal vs. commercial lemongrass tea were done. The results revealed that the panelists perceived more the floral and lemony aromas instead of the others less desirable for them in the artisanal tea, while they identified an aroma of dried straw in the commercial tea at a higher level as compared to the expected lemony and floral aromas, as seen in Table 4. Panelists indicated that both types of tea tested mainly as lemon, although they found the artisanal tea to have a stronger lemon taste than the commercial one. The panelists also identified a near strong sweet taste in the artisanal tea. Finally, we asked panelists to indicate they preferred tea (artisanal vs. commercial), using a Likert scale of 5 options for preferences, with one as not preferred, and five as strongly preferred. The artisanal tea explicitly came forth as the preferred tea with 14 out of 15 preference votes, with a mean 4.5 (SD=0.6) of acceptability, vs. only one vote for preference of the commercial tea, as seen in Table 5. While the overall acceptability of the commercial tea was rather "neither liked nor disliked" (although a high deviation on the rating), the artisanal tea was assessed as very much liked by all respondents.

Table 4: *Panelists Assessment of the Aroma Characteristics of Artisanal Vs. Commercial Lemongrass Tea*

Aroma	Artisanal Tea (Mean $\pm$ SD)	Commercial Tea (Mean $\pm$ SD)
Floral	**3.2 $\pm$ 0.9**	2.0 $\pm$ 1.0
Lemon	**3.4 $\pm$ 0.7**	2.0 $\pm$ 1.0
Walnut	1.1 $\pm$ 0.3	1.4 $\pm$ 0.5
Roasted grain	1.3 $\pm$ 0.6	1.3 $\pm$ 0.6
Brown rice	1.1 $\pm$ 0.4	1.3 $\pm$ 0.6
Dried straw	2.1 $\pm$ 1.0	**2.5 $\pm$ 0.9**
Cut grass	2.3 $\pm$ 1.1	2.0 $\pm$ 0.9
Burnt leaf	1.5 $\pm$ 1.0	1.5 $\pm$ 1.1
Metallic	1.1 $\pm$ 0.4	1.3 $\pm$ 0.8

Ratings for Aroma: 1= absent; 2= faint; 3= moderate; 4= strong

Table 5: *Panelists Assessment of the Taste Characteristics of Artisanal vs. Commercial Lemongrass Tea*

Taste	Artisanal Tea (Mean ± SD)	Commercial Tea (Mean ± SD)
Sweet taste	**2.5 ± 0.9**	1.9 ± 0.7
Sour taste	1.7 ± 0.7	1.5 ± 0.5
Bitter taste	1.3 ± 0.6	1.6 ± 0.8
Astringency	1.6 ± 1.1	1.7 ± 1.3
Lemon	**3.4 ± 0.9**	**2.6 ± 1.0**
Orange	2.1 ± 0.7	1.8 ± 0.7
Grapefruit	1.6 ± 0.8	1.4 ± 0.5
Cut grass	2.1 ± 1.1	2.0 ± 0.8
Burnt leaf	1.3 ± 0.9	1.3 ± 0.5
Metallic	1.3 ± 0.8	1.3 ± 0.6

Ratings for Taste: 1= absent; 2= faint; 3= moderate; 4= strong

4. Conclusions

As described in this paper, we successfully planned and built an agro-industrial factory for the processing of nutritional and medicinal plants commonly used in rural Panama, particularly in the community of El Cacao, district of Capira. We assessed the functionality of the factory, including its capacity to utilize solar energy for drying nutritional and medicinal plants, with favorable results.

Preliminary tests with different plants yielded positive results, as it was possible to reduce the moisture content to recommended levels in shorter times than those reported in the literature for similar processes [3, 6]. Conservation of the organoleptic characteristics including taste, aroma and color were maintained at expected levels during the drying process, and comparable or better than similar commercial products found in the area, as determined by sensory evaluations by a panelist group of community residents. These results were very promising, especially because they suggest that the local population would accept their traditional plants processed in their community.

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