Studies on Solar Drying of Two Liquid Biowastes

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Solar drying is usually done for solid materials, like spices, fruits, fish and meat. But deviating from the usual practice, solar drying of liquid materials was attempted. Liquid wastes like starch water and mature coconut water were subjected to solar drying. Apart from bringing it to a dried form, more importance was given to bring a reuse from these dried materials. This option of reuse could minimize pollution and bring about effective waste management. Energy content of the dried materials was also calculated. But the recovery obtained after drying was in small quantity and drying needed a large surface area. Dried mature coconut water was used as an additive in culture media for orchid seed germination studies in Spathoglottis plicata. It was found that incorporating the mature coconut water concentrate in the culture medium could enhance the seed germination percentage.

Keywords: Solar drying, Biowastes, Starch water, Mature coconut water

Introduction

Energy is any society's fundamental need. It is required to sustain and improve the quality of life. In fact, all forms of energy on the Earth are derived from the sun. Even the conventional forms of energy the fossil fuels had received their solar energy millions of years ago and possess the energy in more concentrated form. These highly concentrated solar energy sources are being used at a rapid rate that they will be depleted in not-too-distant future. Therefore, as these non-renewable energy sources are consumed mankind must turn their attention to longer term, permanent energy sources.

All sources of energy that support life and our existence can be divided into two main categories: (a) non-renewable and (b) renewable. Applications in renewable energy in vital sectors can go a long way in conserving conventional energy supplies. Using solar thermal energy for heating needs makes huge savings in our energy consumption of fossil fuels and cut greenhouse gas emissions.

Solar Dryer — A system that heats the air in the dryers makes use of the solar thermal energy directly. Solar drying is not completely a new technology, but slight improvisation of our age-old practice of open sun drying. Such a technique uses the energy from the sun to heat a stream of air that, in turn, flows by natural or forced convection through a bed of the commodity to be dried. Since the material is contained, there is less contamination, and it is less susceptible to adverse weather conditions. There are many different types of dryers. Solar cabinet dryers¹, solar tunnel dryers², solar mini dryers and solar midi dryers (Designed by Renewable Energy Research Centre, Sacred Heart College, Thevara) are some among them.

Presently, dehydration offers the most efficient method of preserving food. Food preservation by means of dehydration provides a useful technique to meet temporary food shortages. We should also take into account emergency conditions that arise at any time, as a result of droughts, wars or international food shortages³.

Some common problems are encountered during the drying of the materials. Case hardening is one such. This may occur when drying takes place too fast⁴. Higher temperature leads to browning reaction and case hardening which greatly affects the product quality⁵.

It is a general rule that everything is useful in one way or the other. Everything can be put to use if methodologies and technologies develop accordingly.
But in most cases, an optimum use is not brought out of all materials. Then in such cases a large amount is wasted without finding a definite use. Similarly, in our daily life, we come across large amount of biowastes, which are wasted completely or with minimal reuse. Biowastes such as mature coconut water, starch water are some among them. However the extent of usefulness and the economic feasibility of such materials are its limitations.

**Mature Coconut Water**

Kerala is one of the major coconut growing states in India (Asian and Pacific Coconut Community, Statistical Year Book, 2000). The all India final estimate of coconut production accounts that the state’s production in 2000-2001 is 5,496,0 million nuts (Directorate of Economics & Statistics, Ministry of Agriculture, Government of India, 2002). About an average of 60 mL of coconut water is obtained from a breaking of a mature coconut. Then from one million nuts, one can imagine the amount of mature coconut water wasted without any definite use. Tender coconut water is consumed throughout our state as a drink. But mature coconut water finds little use. It is consumed as such or wasted.

**Starch Water**

Rice is the staple food of our country. It is unavoidable in our diets. Starch water could be called as the byproduct obtained from that calorie rich food. Starch makes up the stored food or nutritive reserves of many plants.

If a single kitchen produces a nominal amount of starch water for cooking a single meal, then what about the output of large hotels and restaurants. Being a renewable natural polymer, starch has a multitude of applications.

Solar drying is not usually followed for drying of liquids. Liquids are usually dried for industrial needs, using other techniques. Spray evaporation technique is one such. Thus, references of earlier works on solar drying of liquids could not be obtained.

After a critical evaluation, following objectives were selected for the study:

- To make eco-products by solar drying of the selected materials (mature coconut water and starch water).
- Finding a reuse option for the dried waste materials.
- Biochemical analysis and estimation of energy content of the dried materials.
- Elevating the quality of dried products to a marketable level.

**Materials and Methods**

Drying experiments were entirely dependent on the solar midi dryer (Figure 1) and the prevailing environmental conditions. Solar midi dryer is a medium size version of the solar tunnel dryer. Solar tunnel dryer is having a total collection area of 14 m² and solar midi dryer is having a total area of 8 m² (l=4 and b=2m).

For the present drying experiments, starch water and mature coconut water were selected. Stainless steel trays (l=41.5 cm, b=34.5 cm, depth =2 cm) were used, so as to contain the liquid materials taken for drying.

**Pre-Treatment before Drying**

As a pre-treatment, both the stainless steel trays were washed with hot boiling water. They were air-dried and later rinsed with the material that was to be taken in trays.

Intermittent stirring was practiced at 2 h intervals. This was to ensure heat convection to the lower liquid layers and to avoid the possible chances of case hardening.

**Solar Midi Dryer**

Solar Midi Dryer (Flat Plate Collector Type) (Figure 1) was indigenously designed by borrowing...
the techniques adopted in the solar tunnel dryer with modifications to suit the local domestic, and agricultural needs. The basic building block of the collector is a thin, flat metal plate to absorb the sun’s ample radiation. A fluid, usually water or air is in contact with the absorber plate and circulated by a pump or fan to take away the heat. The plate is painted black to increase its absorption, and is covered with one or two sheets of glass (Figure 1) or plastic to cut down the losses via radiation and convection.

For the drying area, tray system was used (tray size $1 = 1$ m and $b = 2$ m). The tray could be slide in and out on a small trolley. Since the trays masked the $2$ m$^2$ of the whole area of the drier ($8$ m$^2$), the collection area was taken as totally $6$ m$^2$. Solar midi dryer was supported by concrete structures (Figure 1) of height about 1 metre. This is for easy loading and unloading. The whole dryer is covered with floating glass of thickness $4$ mm. In humid tropical countries with frequent rainfall the covering sheet is tilted like a roof (Figure 1), which prevents water entering or flooding the device. To convert solar radiation into heat the top surface of the solar air heater is painted black.$^3$. In solar midi dryer food grade gel coating is used in the absorber areas and fibre reinforced plastic is used to give strength. The air outlet of the dryer is guarded with plastic net to prevent the entry of insects. The solar generator is installed at the inlet of the solar air heater. This enables cooling of the solar generator by forcing the ambient air underneath the back of the module.$^2$

The temperature of the drying air is automatically controlled by the irradiation when using a PV (Photovoltaic) drive. Low airflow rate results in a comparatively high temperature rise. High radiation causes a higher airflow rate, which results in a relatively low temperature increase.

**Mature Coconut Water**

Healthy mature coconuts were selected for the study. After the selection of the mature coconuts, they were broken and coconut water was collected in a stainless steel vessel. Mature coconut water was not blanched since it was obtained in aseptic condition (within the shell) as well as to avoid alteration in chemical composition. After quantifying it was passed through a common kitchen sieve (0.5mm) to avoid fibres. The sieve was held above the stainless steel trays and mature coconut water was passed through it. Mature coconut water was filled in stainless steel trays with legs (Height of legs = $6$cm). Heights of legs for trays were designed in accordance with the height of the entrance for the dryer for easy loading and unloading.

**Starch Water**

Starch water was not blanched (pre-boiled) since it was obtained in a boiled condition. Starch water was collected from more than a single source. Then it was thoroughly mixed. Here the amount of water added to rice and the quality of rice was not standardized because the general composition varies from the cooking patterns. The objective of bringing a reuse to a wasted material through solar drying was given more importance. Starch water was quantified using a measuring jar before pouring into the trays. During drying of starch water, a thick film was seen on the surface. It was broken off every $2$ h with intermittent stirring to avoid possible chances of case hardening and to ensure heat convection to the underneath liquid layers.

During the process of drying the blower was operational while it was receiving insolation in the day times. However, at night the temperature in the dryer came down due to the absence of insolation. Blowers did not work during night since it was PV driven. Starch water and mature coconut water was left in the dryer during night hours. Insolation in the solar tunnel dryer helped retaining some of the temperature during night too.

(i) **Calculating Solar Insolation**

Solar insolation was calculated using the formula$^5$: \[ R_{st} = 33.78 \times n + 261.58 \left( \frac{W}{m^2} \right). \]

where $R_{st}$ is the direct solar radiation above coconut canopy and $n$ is the bright sunshine h/d. Bright sunshine hours were taken as $10$ h/d. It was decided depending on the weather forecast and based on general observation.

(ii) **Temperature Measurements**

The temperature readings were taken using a bulb thermometer at $2$ h intervals between $9.00$ am to $5$ pm of the ambient air and at the inlet and outlet of the dryer for $2$ d.
(iii) Relative Humidity

Relative humidity was measured using an air guide instrument (USA). Readings were taken at the inlet and outlet of the dryer and of the ambient air. It was expressed in percentage.

(iv) Biochemical Analysis of Samples after Drying

Total carbohydrates and soluble sugars were estimated by Anthrone method, proteins by Lowry et al. method, starch by I-KI method, and lipids by the Bligh and Dyer method described in reference 9. Analyses were followed with slight modifications by trial and error basis and according to the nature of the sample. All estimations were made, using a Spectrocolorimeter (Systronics 103) except lipids (difference in wt). The samples were analyzed in triplicates.

(v) Energy content of the dried materials

After the estimation of protein, carbohydrate and lipid the weights obtained in grams were converted into kilocalories (1g protein = 4 kcal, 1 g carbohydrate = 4 kcal, 1 g fat = 9 kcal).

Energy content of the dried materials was calculated separately.

(vi) Tissue Culture Experiments with Dried Mature Coconut Water

Dried mature coconut water was tested as an additive in tissue culture media for the seed germination in orchids (Spathoglottis plicata). 1g, 2g, and 3g of the dried material was added to 100 mL MS media. Germination rate was noted after 15 and 30 d, respectively.

Results and Discussion

Starch water and mature coconut water showed good drying signs. Summary of the experiments conducted and important observations is given in Table 1.

Dried Mature Coconut Water

2000 g of the mature coconut water was dried to a more viscous, jelly like form within 32 h. After drying, it showed a recovery of only about 40g/L. When tasted, it was having a disagreeable taste. The experiment was repeated with no better results. An effort to reduce the drying time of mature coconut water was carried out. This was performed so as to maintain it as a watery medium. But the taste of the product was not agreeable.

Dried Starch

About 2000 g of starch water was taken for drying. End product of the starch water drying appeared as dried brown flakes. It took about 30 h to become flakes. Flakes were large and leathery and recovery was very feeble when compared with the initial volume. About 35 g was the recovery from 2000 g of the starch water. One set of starch water was dried for double the time (60 h) and that too finally became dried brown flakes. But the size of the flakes was different from that of the earlier dried ones. It was more powdery than the earlier 30 h dried product. It was found that the dried starch water could be added as a substitute for the commonly used starch ingredient in compound cattle feed after considering the economic viability of production.

Results of the Experiments Conducted

(i) Calculation of Average Solar Insolation

Average solar insolation for the two months when drying experiments were conducted was obtained from Pyrenometre readings, which averaged to about 400W/m²-700W/m². Average solar insolation calculated from a similar study (solar drying of garcinia⁴) complied with the average insolation values obtained. Average solar insolation for the two months was also calculated using the formula⁵:

\[ R_{st} = 33.78 + 261.58(n/W/m²), \]

where \( R_{st} \) is the direct solar radiation above coconut canopy and \( n \) is the bright sunshine h/d.

This was in agreement with the average insolation calculated from pyrenometre readings and was within the range.
(ii) Temperature

Temperature and relative humidity readings both inside the dryer and of the ambient air were taken. The temperature of the ambient air was only 31 to 35°C, while the temperature inside the dryer was high (55-65°C). The temperature inside the dryer varied according to varying insolations.

(iii) Relative Humidity

Ambient air showed a relative humidity of 60 percent, while inside the dryer, the relative humidity was considerably reduced and it ranged between 17 to 20 percent.

(iv) Observations during the Drying Experiments (Table 1)

Each material behaved differently during the drying experiments. Dried mature coconut water appeared as a jelly like viscous form. It stuck to the steel trays and had to be wiped off. In the case of dried starch water, it could be easily removed from the trays and did not show a sticky nature. The variation between the longer dried and less dried starch water was the difference in its size.

(v) Biochemical Analysis of the Dried Materials (Figure 2)

Biochemical analysis of the dried materials gave the amount of carbohydrate, soluble sugars, starch, lipids, and proteins in the dried samples (Figure 2). Among the dried samples, starch water, which was dried for long, showed the highest values for total carbohydrates, starch, and proteins when compared with the rest of the samples. While dried mature coconut water showed the highest value for soluble sugars and lipids.

(vi) Energy Content of the Dried Materials (Figure 3)

Total energy content of the dried samples was expressed in 100 g of the samples. From the calculation of energy content of the dried samples, over dried starch showed the highest energy content among the samples.

(vii) Tissue Culture Results Using Dried Mature Coconut Water (Figure 4)

Dried mature coconut water was tried as an additive in tissue culture media. This culture medium was used in the seed germination of orchids.
(Spathoglottis plicata). The germination rate noted in orchids after 15 and 30 days showed enhancement in growth (Figure 5) for 1 g and 2 g/100 mL culture media. After 30 days, in both the cases, germination rate was noted as 80 per cent. For 3 g/100 mL culture media the germination rate slowed down. This inhibitory behaviour is usually expressed by growth promoting substances at increased amounts.

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References