Experimental Investigations on Electrical Heat Assisted Drying of Cashew Kernels

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Abstract: Drying is an important process in food preservation. In cashew processing industries cashew kernels are dried for easy peeling of the thin brownish sticky layer known as testa. The average moisture content of 13% of the cashew kernels needs to be reduced to 5% for proper peeling action. Drying can achieved either by traditional drying methods or through dryers. Due to control of the air properties in indirect drying cashew kernels can be dried at faster rate and can retain their quality. Air flow passage also plays an important role in drying process. The objective of the study is to investigate experimentally the feasibility of drying chamber for drying of cashew kernels using electrically assisted heating. An electrical heat assisted drying system is designed and developed using locally available materials. The system uses three different drying chambers that are designed and tested for optimum drying rate of cashew kernels in three separate experiments. Drying chamber without baffle plates has resulted in reduction in moisture content to required level by 5% in three hours with drying rate of 2.8 kg/h against 6.5% and 6.8% in single tray version and four trays with baffle plate version. The drying efficiency of drying chamber is found to be 30.54%.

1. Introduction
Cashew is one of the important tropical crops of India. It is grown mainly in peninsular states of India particularly along the coastal states. It is an important nut crop that provides food, employment and hard currency to the nation [1]. Cashew industries are categorized as cottage, small, medium and large scale industries. Dakshina kannada district, in the state of Karnataka, India has more than 350 cashew processing industries. All these industries use wood, kerosene and electricity for their thermal energy needs. Drying is one of the important processes in cashew processing. It is basically used to remove high moisture content of the cashew kernels for its safe preservation and ease of peeling process. Present methods of drying the cashew kernels use conventional fuels like kerosene, diesel, electricity and wood. Thermal energy produced by burning these fuels is used to generate steam to heat the air that dries the cashew kernels in borma. Conventional fuels used for burning in boilers are costly, depleting in nature, pollutes the environment and also responsible for global warming [2]. Energy is the most important, critical and vital component in these rural agro industries for development, employment generation and economic growth. The different unit operations/methodologies employed by cashew industry in India for processing depend on the variety of raw material, location,
technological mechanization and availability of secured energy supply. The most energy- and time-intensive unit operations in cashew processing are drying of raw seed in open sun, steaming of raw nut and kernel drying with electrical energy. Small scale industries engaged in batch production of 15 kg/batch, 30 kg/batch & 60 kg/batch have electrical energy consumption of 763.58, 696.39 & 504.28 MJ/1000 kg of raw cashew nut seeds [3]. The cashew kernel coming from the cutting and separation section in processing industries contains a brownish cover, known as ‘testa’, over it. To remove this cover and also control the moisture content, kernels are exposed to prolonged and controlled heating with hot air in a closed chamber at 65–70 °C in perforated tray for 6-8 h. About 5-8% of moisture used to be removed from the kernels in the process [4].

The energy consumption for cashew processing to produce the same quantity of similar products revealed wide variations in energy intensity, ranging from 4.43 to 8.66 kg of fuel wood per kilogram of kernel. This variation in energy consumption reveals the scope for energy conservation of the order of 30–48% [5]. Electrical dryers have shown thermal efficiencies as high as 37 % and 69.5% in case of ginger and banana drying respectively [6-7].

This paper focuses on study of drying cashew kernels for controlling moisture content and to help peeling of testa over it with objectives as follows.

- To design and develop an electrical drying system for cottage industries for drying cashew kernels
- Validate the designed dryer/s suitability for drying cashew kernels
- To carry out testing on developed electrical dryer system for drying cashew kernels and evaluate its overall thermal efficiency

2. Design & Construction

The setup is designed considering the cashew processing industries having minimum sized production of 15 kg. With the basic parameters of reducing moisture content from 13% to 5% and a product temperature and drying temperatures of 32 °C and 64°C, the drying time is considered as 4 hours. The energy required to dry is 2708 kJ with mass of air of 168 kg. The mass flow rate is 0.12 kg/s. Thus a fan or a blower that can supply a volume flow rate of 0.12 m³/s is chosen. The amount of energy required to heat 168 kg of energy is 5204 kJ for the duration. Considering 35% efficiency, the capacity heater is found to be 1kW. The blower with the designed specifications is purchased from the local market. A coil heater of 1 kW capacity is wound on a thin copper tune of wall thickness 1.5mm and diameter 22 mm. This is insulated with 12 mm thick asbestos rope of two layers wrapped with alumina sheet to avoid heat loss to the surroundings. The heater is connected to the cabinet dryer with a rubber hose and tightly clamped at both ends to avoid leakages. Blower end is inserted directly to the heater and there will be no leakages across the system. The whole assembly is mounted on a steel frame to facilitate the connection of required instrumentation and testing. A schematic view of sectional details of heater assembly is presented in Figure 1.

![Schematic view showing sectional details of heater assembly](image)
3. Experimentation

Experiments are conducted to test the developed experimental setup for drying cashew kernels using three different drying chambers. In each test one kg of cashew kernels brought from nearby cashew processing industry is used for drying. These are the cashew kernels that are ready to send to the drying section of the industry after shell cutting process. Cashew kernels are loaded in the trays after weighing in a precision weighing scale. First two tests have duration of four hours while last one has three hours. In all tests readings are taken on half hourly basis for temperature at different points and moisture content. After each test the cashew kernels are weighed in the same precision weighing scale to find the final weight. A thumb rule is followed for proper drying of cashew kernels in cashew processing industries is that there has to be reduction in weight by 6% after drying. That is 1000kg load has to be reduced to 940kg after drying. The same rule is followed in each testing along with measurement of moisture content using a digital moisture content test instrument for cross verification. Following are the three tests conducted.

Experiment 1: Dryer with single tray
Experiment 2: Dryer with four trays and plain baffle plates & perforated baffle plates
Experiment 3: Dryer with four trays but without baffle plates

3.1 Dryer with single tray

Test is conducted on 21 March 2015 at Udupi city, Karnataka, India. The experimental setup is tested initially on no load run and all the parameters like temperatures at different points, relative humidity, and velocity of air are checked. The drying chamber is designed for 5kg but for test purpose equipped with only middle tray. The setup is allowed to run for one hour in idle condition to reach steady state. Drying chamber is loaded with one kg of cashew kernels. Temperatures, humidity, velocity and moisture content readings are taken. The mass of the cashew kernels after drying is found to be 955g. There is a reduction in weight of 45g against expected 60g. The analysis of the experiment shows an uneven distribution of heat in the drying chamber. The schematic view of the experimental setup is shown in figure 2.

Figure 2. Schematic view of EHD system with single tray drying chamber

3.2 Dryer with four trays and plain & perforated baffle plates

Second experiment is conducted on 28 April 2015 as the desired results are unable to meet in experiment 1. A small cabinet type drying chamber with four trays having capacity each 250 g of
cashew kernels. This makes the total capacity of cabinet drying chamber 1 kg. Baffle plates are included in the design to retain the heat and also acts as a guide to direct the working fluid through all the four trays. The inlet is given at the top and exit at the bottom. Hot air flows through trays counting 1 to 4 from top to bottom. The results of the experiment conducted show a weight reduction of 35g against 60g required. The final weight of the dried cashew kernels is found to be 965 g. This is again because of improper distribution of the heat to the product in drying chamber. There was no much of improvement with perforated baffle plates. The drying chamber has five trays having total capacity of 15 kg. Each tray can accommodate 3 kg of cashew kernels. Figure 3 shows the schematic view of experimental set up with four tray drying chamber with baffle plates.

![Figure 3. Schematic view of EHD system with four tray drying chamber having baffle plates](image)

3.3 Dryer with four trays but without baffle plates
Keeping all other conditions same third experiment is conducted on 29 April 2015. The baffle plates in the drying chamber are removed and only four trays are retained at equidistance between them. Fresh one kg of cashew is loaded for testing. Experimental results of three hours duration show a final weight as 932g which is 6.5% weight reduction. The moisture content is found to be 5.5%. The dried cashew kernels are given for hand peeling in the processing industry for testing. All the kernels are peeled; found good in colour and had better taste. The pictorial view of the experimental setup along with instrumentation used and drying chamber with four trays but without baffle plates is shown in figure 4.

![Figure 4. Pictorial view of the drying chamber with four trays](image)
Table 2 shows the important results of experimental set 3 and energy balance for drying chamber. The drying chamber has an efficiency of 30.54% with drying rate of 2.68 kg/h. Figure 5 shows the schematic view of drying chamber showing energy balance.

### Table 1: Energy balance of drying chamber of EHD system

| Sl. No. | Description       | Symbol  | Value   |
|---------|-------------------|---------|---------|
| 1       | Energy entering   | $q_{in}$| 884 kJ  |
| 2       | Energy utilized   | $q_{utilized}$ | 270 kJ |
| 3       | Energy lost       | $q_{lost}$ | 339 kJ |
| 4       | Energy let out    | $q_{out}$  | 150 kJ  |
| 5       | Energy unaccounted| $q_{un accounted}$ | 125kJ  |
| 6       | Efficiency        | $\eta_{dc}$ | 30.54 % |
| 7       | Drying rate       | $DR$    | 2.68 kg/h |

![Schematic view of drying chamber showing energy balance](image)

**Figure 5.** Schematic view of drying chamber showing energy balance

### 4. Instrumentation

The complete instrumentation used for experimentation with specifications is given in the table 1.

### Table 2: Specification of the instrumentation used

| Sl. No. | Instrument            | Specification                                                                 |
|---------|-----------------------|-----------------------------------------------------------------------------|
| 1       | Blower                | Power input : 220V, 60W, 50-60Hz, 16000rpm                                   |
| 2       | Heater-Coil type      | Power input : 2000 W, 230V, 50Hz                                            |
| 3       | Anemometer            | Measuring ranges: 0.4-20m/s, Resolution: 0.1m/s, Accuracy: +/-0.2m/s          |
| 4       | Temperature indicator | Measuring ranges: -10 to 50 °C, Resolution: 0.1°C, Accuracy: +/-0.5°C        |
| 5       | Thermocouples         | K type, Range 0-180°C                                                        |
| 6       | Moisture meter        | Wood type select function, Range: 2-70%, Resolution : 0.5%, Power supply: 9V, Product size : [143×59×32]mm |
| 7       | Weighing scale        | Model: SA1torius, Range : 0.1mg-22g                                         |
| 8       | Hygrometer            | Range : 20-95% RH and 0-60°C, Resolution : 0.1% RH, Battery : 9V, Product size : [164×76×45]mm |
| 9       | Clamping meter        | Range : 300-600A, Volts : 600V, Resolution : 0.1 A and 0.1V, Accuracy : 1% +/- 5 digits, Size : [207×75×34]mm, Weight : 265g, Operating temperature : 0 - 60°C |
5. Results & Discussion

Drying is combined heat and mass transfer activity. Heat-assisted dryers create warm air flow inside the dryer to speed up drying. The majority of energy used in heated air dryers is actually used to heat the fluid-air. Electricity for moving air is only a small fraction of the air heating costs, which depend on the initial and final moisture contents of the product.

Three experiments are conducted to find the suitable design to dry cashew kernels. Experiment 1 & 2 are conducted for four hours duration. Figure 6 shows the variation of exit temperature and moisture content of the experiment 1 & 2 respectively. It is observed that the moisture content curves vary between 13 to 6.8 & 6.5% respectively for experiment 1 & 2. Variation of exit temperature is in the range of 47 to 52 °C and 33 to 46 °C respectively for experiment 1 & 2. The average temperature for these being 48 & 45 °C indicates lot of energy is going out of the drying chamber without use. Hence the required objective of reducing moisture content is not achieved.

![Figure 6. Variation of exit temperature and moisture content against hours of Expt. 1 & 2](image)

Figure 7 shows variation of moisture content of the product for all the three experiments 1, 2 & 3. In experiment 1 & 2 the final moisture content found is 6.8 and 6.5 % respectively for test duration of four hours. At this level it is difficult to peel off the testa in peeling section. In third experiment a safe level of 5.5% is achieved in test duration of three hours. In experiment 3 the drying rate is found faster than other two and the required level of moisture content is achieved.
Various factors that affect the drying process are mass flow rate of air, humidity, and temperature. The flow passage decides the heat distribution in the drying chamber. Figure 8 shows comparison of reduction in weight in grams of the cashew kernels before and after drying. The final weight of the product after drying is 955, 965 & 932 g respectively in all the three experiments. In the third experiment both the percentage moisture content and the reduction in weight after drying are achieved with drying rate of 2.8 kg/h and drying efficiency of 30.54%.

![Figure 7. Time Vs. Variation of moisture content against time during experimental trials](image1)

![Figure 8. Weight of cashew kernels before and after drying](image2)
6. Conclusions

Based on the experiments conducted following conclusions are drawn.

The drying is the one of the activities where the major energy is consumed in the processing of cashews. Proper design and functioning of the drying chamber is important to have correct drying and at optimum time.

- In the first experiment, even though the temperature of the air is adequate because of low velocity the drying rate is found less.
- In the second experiment, temperature of the air is maintained with increase in velocity. The improper passage of the air in the drying chamber by inclusion of the baffle plates affected the drying process.
- In the third experiment, both the parameters velocity and flow passage are maintained and proper air flow helps in drying process. The objective of reduction in the moisture content for 5% is achieved in three hours.
- The drying rate is optimized to 2.8 kg/h resulting in energy saving compared to other two experiments.
- The drying chamber efficiency is found to be 30.54%
- The results of the experiment are used to design a solar drying system for further research by the author that replaces the heater section.

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