

## Table of Contents

Chapter	Topics	Page No.
	List of tables	I
	List of Figure	II-III
	Nomenclature	IV
<b>1</b>	<b>Introduction</b>	<b>1-12</b>
1.1	Drying principles	1
1.2	Internal mechanism of liquid flow	3
1.3	Periods of Drying	3
1.3.1	Constant-rate period	4
1.3.2	Falling-Rate Period	5
1.3.3	Estimations for total drying time	5
1.4	Solar drying technology	5
1.4.1	Classification of Solar Dryers	6
1.5	Working principle	7
1.5.1	Open sun drying (OSD)	7
1.5.2	Direct solar drying (DSD)	7
1.5.3	Indirect solar drying (ISD)	8
1.5.4	Hybrid solar drying (HBD)	8
1.6	Types of solar dryer	9
1.6.1	Passive Solar Drying Systems	9
1.6.1.1	Indirect-type passive solar-energy dryers	9
1.6.2	Active solar drying systems	9
1.6.2.1	Indirect-type active solar drying systems	10
1.6.2.2	Direct-type active solar-energy drying systems	10
1.6.3	Hybrid-type active solar-energy dryers	10
1.7	Objectives	12
<b>2</b>	<b>Literature review</b>	<b>13-16</b>
2.1	Solar dryer	13
<b>3</b>	<b>Experimental setup and Methodology</b>	
3.1	Schematic diagram of hybrid solar –electrical dryer	17
3.2	System design	17
3.2.1	Drying box	18
3.2.2	Flat plate collector	18

	3.2.3	Electrical air heater box type	19
	3.2.4	Temperature controller and blower speed controller	20
	3.2.4.1	Specification of temperature controller	20
	3.2.5	Centrifugal blower	20
	3.6	Measuring instruments	21
	3.7	Methodology	22
	3.7.1	Mathematical modeling of drying curves	22
	3.7.2	Efficiency calculation	22
<b>4</b>		<b>Results and discussion</b>	<b>25-38</b>
	4.1	Behavior of solar–electrical dryer without load	25
	4.1.1	Measurement of temperature variation of different elements of the dryer	25
	4.1.2	Energy contribution of hybrid solar-electrical dryer	27
	4.2	Behavior of hybrid solar–electrical dryer with load	28
	4.2.1	Drying of potato slice at 50°C	28
	4.2.2	Drying of potato slice at 60°C	31
	4.2.3	Energy contribution of hybrid solar-electrical dryer for with load	33
	4.3	Effect of temperature on moisture content of potato slice drying by hybrid dryer	33
	4.4	Drying of potato slice by solar	34
	4.5	Drying of potato slice by electric air heater 50 0C	36
	4.6	Drying of potato slice by electric air heater 60 0C	27
	4.7	Efficiency of different drying mode	38
<b>5</b>		<b>Conclusions and Future work</b>	<b>39</b>
		<b>References</b>	<b>40-41</b>

---

## List of Tables

---

<b>Table No.</b>	<b>Particulars</b>	<b>Page No.</b>
Table No. 1.1	Commonly encountered terms in psychrometry and drying	2
Table No. 3.1	specification of the centrifugal blower used in the experiment	20
Table No. 3.2	specification of the thermocouple	21
Table No. 3.3	specification of Pyranometer	21
Table No. 3.4	specification of anemometer	21
Table No. 4.1	Energy contribution of solar collector, electrical heater and blower for the hybrid solar electrical dryer	28
Table No. 4.2	Energy contribution of solar collector, electrical heater and blower for the hybrid solar- electrical dryer for drying potato slice at 50°C and 60°C	33

---

## List of Figure

Figure No.	Particulars	Page No.
Fig. 1.1	Drying period curves	4
Fig. 1.2	Total horizontal solar insolation for some developing countries	6
Fig. 1.3	Typical solar energy dryer designs	6
Fig. 1.4	Working principle of open sun drying	7
Fig. 1.5	Working principle of direct solar drying	8
Fig. 1.6	Working principle of indirect solar drying system	8
Fig. 1.7	Features of a typical distributed- type active solar energy dryer	10
Fig. 1.8	Schematic diagram of an indirect active hybrid solar–electrical dryer	11
Fig. 3.1	Schematic diagram of hybrid solar-electrical dryer	17
Fig. 3.2.a	Side view of drying chamber	18
Fig. 3.2. b	Drying chamber	18
Fig. 3.2.c	Food tray	18
Fig. 3.3	Flat plate collector	19
Fig. 3.4.a	Top view of electric heater chamber	19
Fig. 3.4.b	Electric heater chamber	19
Fig. 3.5	Temperature controller	20
Fig. 3.6	Temperature sensor	20
Fig. 3.7	Relay	20
Fig. 3.8	Blower speed	20
Fig. 3.9	Pyranometer	23
Fig. 3.10	Thermocouple	23
Fig. 3.11	Universal oven	23
Fig. 3.12	Anemometer	23
Fig. 3.13	Centrifugal blower	23
Fig. 3.14	Power meter	23
Fig. 3.15	Experimental setup	24
Fig. 3.16	Sample of dried potato slice	24
Fig. 4.1	Solar intensity and temperature variation of different elements of the dryer	25
Fig. 4.2	Solar intensity and temperature variation of different elements of the dryer at constant temperature 50°C	26
Fig. 4.3	Solar intensity and temperature variation of different elements of the dryer	27

	at constant temperature without load	
Fig. 4.4	Solar intensity and temperature variation of different elements of the hybrid dryer at 50°C	28
Fig. 4.5	moisture ratio versus drying time of different tray using hybrid solar-electrical dryer	29
Fig. 4.6	Drying rate (kg water/kg dry matter) versus drying time at 50°C of different tray using hybrid solar-electrical dryer	29
Fig. 4.7	Overall drying rate variation versus drying time at 50°C using hybrid solar – electrical dryer	30
Fig. 4.8	Drying rate (kg water/kg dry matter .h) versus drying time at 50 °C using hybrid solar –electric dryer	30
Fig. 4.9	Solar intensity and temperature variation of different elements of the dryer at 60°C	31
Fig. 4.10	Moisture ratio versus drying time at 60°C using hybrid solar electrical dryer	32
Fig. 4.11	Drying rate versus drying time at 60°C using hybrid solar electrical dryer	32
Fig. 4.12	Moisture ratio versus drying time (h) at 60°C using hybrid solar electrical dryer	32
Fig. 4.13	Moisture ratio versus drying time (h) at 50°C and 60°C	33
Fig. 4.14	Drying rate (kg water/kg dry matter) versus drying time (h)	34
Fig. 4.15	Solar intensity and temperature variation of different elements of the dryer using solar drying	34
Fig. 4.16	Moisture ratio versus drying time (h) of different tray using solar	35
Fig. 4.17	Drying rate (kg water /kg dry matter.h) versus Drying time (h) using solar	36
Fig. 4.18	Moisture ratio versus drying time (h) using solar	36
Fig. 4.19	Moisture ratio versus drying time (h), drying using solar	36
Fig. 4.20	Overall moisture variation with drying time (h) drying by electric air heater	37
Fig. 4.21	Moisture ratio versus drying time (h) drying using electrical air heater	37
Fig. 4.22	overall Moisture ratio versus drying time (h) drying using electrical air heater	38
Fig. 4.23	Efficiency of different drying mode	38

## Nomenclature

$X_w$	Moisture content in wet basis
$X_d$	Moisture content in dry basis
$t$	Time
$m$	Mass
$m_w$	Mass of moisture
$m_d$	Mass of dry matter
$\theta_c$	Constant rate period
$\theta_f$	Falling rate period
$\theta_t$	Total drying time
$V$	Voltage
$v$	Air velocity
$X_0$	Initial water content
$X_e$	Water content of balance
$X_t$	Water content at the moment $t$
$X_{t+\Delta t}$	Water content at the moments $t + \Delta t$