ABSTRACT

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UTILIZATION OF SOLAR ENERGY FOR DRYING LEAVES OF MEDICINAL AND AROMATIC PLANTS

Egypt is one of the sun belt countries, having a great numbers of sunshine hours per year. The solar energy which generated from sun radiation is used for drying many agricultural crops especially medicinal and aromatic plants. These plants are cultivated in Egypt for both local consumption and export.

Peppermint and sweet basil are the most important medicinal and aromatic plants all over the world especially in Egypt.

The main objectives of this investigation were to:-

1. Construct a appropriate solar drying system for drying the leaves and different parts of crops especially medicinal and aromatic plants.
2. Measure and investigate some of physical and chemical properties.
3. Evaluate the thermal performance of the solar air collector.
4. Find out the optimum temperature and air flow rate for drying the leaves of peppermint and sweet basil.

The conventional sun drying method of peppermint leaves gave the worst average drying rate of 0.32 % db/min and 0.21 % db/min due to long drying period of 23 hr. and 33 hr., with average drying air temperature of 31.0 °C and 20.5 °C, total chlorophyll of 35.40 and 42.00 mg. per 100 gms sample, means volatile oil percentage of 1.27 % and 1.62 %, means volatile oil specific gravity were 0.917 and 0.919 means

volatile oil refractive index of 1.47 and 1.48, means volatile oil optical rotation of -19 and -20 and menthol content of volatile oil percentage of 32.38 % and 41.60 % in 2001 and 2002 seasons respectively.

While, the conventional sun drying method of sweet basil leaves gave the worst average drying rate of 0.25 % db/min and 0.12 % db/min due to long drying period of 27 hr. and 39 hr., with average drying air temperature of 30.1 °C and 21.9 °C, total chlorophyll of 16.8 and 17.8 mg. per 100 gms sample, means volatile oil percentage of 0.82 % and 0.86 %, means volatile oil specific gravity of 0.934 and 0.928 gm/cm^3, means volatile oil refractive index of 1.477, means volatile oil optical rotation were -20 and -19 and linalool content of volatile oil percentage of 38.45 % and 42.10 % in 2001 and 2002 seasons respectively.

The solar air drying method of peppermint leaves gave the average drying rate ranged from 0.52 % to 0.62 % db/min and 0.32 % to 0.34 % db/min due to short drying period ranged from 12 to 14 hr. and 21 to 24 hr., with average drying air temperature ranged from 34.7 to 39.4 °C and 24.5 to 33.5 °C, total chlorophyll ranged from 40.1 to 46.0 mg. per 100 gms sample and 49.9 to 59.2 mg. per 100 gms sample, means volatile oil percentage ranged from 2.48 to 2.80 % and 2.68 to 2.87 %, means volatile oil specific gravity ranged from 0.919 to 0.921 and 0.918 gm/cm^3, mean volatile oil refractive index of 1.47 and 1.48, means volatile oil optical rotation of -20 and -20 to -21 and menthol content of volatile oil percentage ranged from 39.62 to 40.06 % and 45.5 to 50.20 % in 2001 and 2002 seasons respectively.

While, solar air drying method of sweet basil leaves gave the average drying rate ranged from 0.37 % to 0.45 % db/min and 0.24 % to 0.26 % db/min due to long drying period ranged from 15 to 18 hr. and 26 to 28 hr., with average drying air temperature ranged from 34.4 to 38.0 °C and

24.9 to 28.5 °C, means total chlorophyll ranged from 19.3 to 22.5 mg. per 100 gms sample and 20.5 to 23.7 mg. per 100 gms sample, means volatile oil percentage ranged from 1.76 to 1.82 % and 1.91 to 2.03 %, means volatile oil specific gravity ranged from 0.943 to 0.936 and 0.930 gm/cm^3, means volatile oil refractive index of 1.477 and 1.478, means volatile oil optical rotation of -20 and -18 to -20 and linalool content of volatile oil percentage ranged from 47.92 to 54.81 % and 48.4 to 55.4 % in 2001 and 2002 seasons respectively.

The daily average heat removal factor and parameters of solar collector increased when the air flow rate increased, although the effect is not as pronounced at higher air flow rates. The daily average heat removal factors, F_R with three levels of air flow rates (9.56, 6.64 and 4.06 m^3/min) were 0.8123, 0.7684 and 0.7422 respectively. Means while the solar air collector parameters, F_RU_L were 6.2388, 5.4448 and 4.3151W/ (m^2. °C), respectively. The overall heat transfer coefficient of solar collector at air flow rates (9.56, 6.64 and 4.06 m^3/min) were 7.9602, 7.0755 and 5.8038 W/ (m^2. °C), respectively.

The maximum instantaneous thermal efficiency of solar air collector with three levels of air flow rates (9.56, 6.64 and 4.06 m^3/min) were 64.14 %, 61.58 % and 59.31 % respectively.

Finally, applying the solar air drying method in drying of peppermint and sweet basil at air flow rates range of (4.06 – 6.64 m^3/min) is recommended to utilize in commercial drying. The product has the best drying, physical and chemical characteristics.

TABLE OF CONTENT

NOMENCLATURE

A	is the apparent solar radiation at air mass equals zero, W/m^2
A'	is the cross section area of air pipe, m^2
A_C	is the effective solar air collector surface area, m^2
A_O	is the constant dependent on the agricultural material dimensionless.
ADT	is the accumulated drying time, hour.
B	is the atmospheric extinction coefficient, dimensionless
C	is the sky diffuse radiation factor, dimensionless
C_p	is the air specific heat, kJ / (kg. $^{\circ}C$)
C.S.D.M	is the conventional sun drying method.
DR	is the drying rate, % (db)/min.
e	is the represents angle of refraction decimal
E.E.D.C	is the Egyptian Exports Development Center
EMC (dw)	is the equilibrium moisture content, % web basis
EMC (db)	is the equilibrium moisture content, % dry basis
EMCT	is the equilibrium moisture content time, hour
F_R	is the heat removal factor, dimensionless
F_{sg}	is the angle factor between the tilted surface and the ground, dimensionless
F_{ss}	is the angle factor between the tilted surface and the sky, dimensionless
H	is the hour angle, degree.
i	is the angle of incidence

I	is the hourly solar radiation incidence, W/m^2
I_d	is a diffuse sky radiation, W/m^2
I_{DN}	is the direct normal solar radiation incidence, W/m^2
IMC (wb)	is the initial moisture content, % wet basis
IMC (db)	is the initial moisture content, % dry basis
I_o	is the extraterrestrial solar radiation, W/m^2
I_{sc}	is the solar constant W/m^2
I_{mi}	is the main day of direct solar radiation on a horizontal surface for i th month, W/m^2
I_r	solar radiation reflected from surrounding surfaces W/m^2
I_t	is the total solar radiation incidence on a collector surface w/m^2
I_t (av)	is the average hourly total solar radiation incidence, w/m^2
K	is the drying constant, 1/hr
L	is the latitude angle taken positive sign north of the equator
L.S.$D_{0.05}$	is the least significant difference
m	is the air mass flow rate, kg/sec.
MC	is the moisture content at time t, % dry basis
MR	is the moisture ratio, decimal
MC (wb)	is the moisture content wet basis %.
MC (db)	is the moisture content dry basis %
n	is the number of day of the year $1 \leqq n \leqq 365$
n'	is the index of refraction of the fewer dens.
N'	is the index of refraction of the more dens medium
N	is the day length, hr
No	is the constant dependent on the agricultural material

O.D	is the optical density (read of spectrophotometer).
OR	is the optical rotation of volatile oil
PSD	is the plastic solar dryer
Q	is the air flow rate, m^3/min
Q1	is the air flow rate, (9.56 m^3/min)
Q2	is the air flow rate, (6.64 m^3/min)
Q3	is the air flow rate, (4.06 m^3/min)
Q_L	is the thermal energy losses, watt
Q_S	is the energy storage in the collector material, watt
Q_U	is the useful heat gain, Watt
RH	is the relative humidity of ambient air, %
RH (av)	is the average relative humidity of ambient air, %
RI	is the refractive index of volatile oil
SAD	is the solar air drying method
SAD1	is the solar air drying method at air flow rate equals 9.56 m^3/min
SAD2	is the solar air drying method at air flow rate equals 6.64 m^3/min
SAD3	is the solar air drying method at air flow rate equals 4.06 m^3/min
SG	is the specific gravity of volatile oil
S.T	is the solar time, hour
t	is the drying time, hr
TADT	is the total accumulated drying time, hour
T_a	is the ambient air temperature, °C
T_C	is the constant value
T (av)	is the average solar air temperatures, °C
Ta (av)	is the average ambient air temperature, °C

T_i	is the inlet solar collector air temperature, °C
T_i (av)	is the average inlet solar collector air temperature, °C
T_o	is the outlet solar collector air temperature, °C
T_o (av)	is the average outlet solar collector air temperature, °C
$T_{P, m}$	is the absorber surface mean temperature, °C
Trea.	is the treatments
T. ch	is the total chlorophyll (mg.per 100 gms. Sample)
U_L	is the overall heat losses coefficient, W/ (m^2.°C)
V	is the air flow rate, m^3/ (m. s)
V^*	is the constant volume of acetone (mg.)
V'	is the air velocity, m/sec
V_o	is the volume of the volatile oil, (cm^3)
VO	is the volatile oil percentage, %
W	is the weight of sample (gm.)
wb	is the wet basis %
Ww	is the water mass, gr.
Wd	is the dry mass, gr.
W_I	is the weight of sample gr. (25gr.)
X_o	is the percentage of the volatile oil, %
Z	is the zenith angle
β	is the solar altitude angle above the horizontal, degree.
ϕ	is the solar azimuth angle, Deg
δ	is the solar declination angle, Deg

θ	is the solar incidence angle, Deg
ω	is the sunset hour angle, Deg
ωr	is the sunrise hour angle, Deg
ρ_g	is the reflectance of the ground
ρ_o	is the density of the volatile oil (gr. / cm^3)
Σ	is the surface tilted angle, degree
$\tau\alpha$	is the transmittance- absorptance product of cover and absorber surface, dimensionless
η	is the instantaneous thermal efficiency, decimal.
η_{max}	is the maximum possible instantaneous solar collector efficiency