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86/9/24:

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E-mail: sadeghi@itvhe.ac.ir

\*

40 20 ( ) %51/8 %20/9

0/1904 W/m°C 0/1145 %51/8 %20/9  
0/1448 40 20  
( ) 0/1585 W/m°C  
%5

## Bulk Thermal Conductivity of Unhulled Pistachio Nuts

A Sadeghi<sup>1\*</sup>, T Tavakoli<sup>2</sup>, B Ghobadian<sup>2</sup>, MH Khoshtaghaza<sup>2</sup> and S Minaei<sup>2</sup>

<sup>1</sup>Institute of Technical & Vocational Higher Education of Jihad Keshavarzi, Tehran, Iran

<sup>2</sup>Department of Agricultural Machinery, Tarbiat Modares University, Tehran, Iran

\*Corresponding author: E-mail: sadeghi@itvhe.ac.ir

### Abstract

One of the most important thermal properties of unhulled pistachio nuts, namely bulk thermal conductivity, was evaluated as the function of moisture content and temperature. The moisture content of nuts ranged from 20.9% on the wet basis to 51.8% (moisture content at harvest time) and the temperature ranged from +20°C to +40°C. In order to measure the thermal conductivity of agricultural materials, a specific probe was developed. Thermal conductivity was measured in transient state by calculating the maximum instant slope, using the line heat source which was

assembled in the probe. Bulk thermal conductivity varied significantly with moisture content and temperature. It ranged from 0.1145 to 0.1904 W/mK and increased with moisture content in the range of 20.9-51.8% on the wet basis. Furthermore, increasing the temperature from 20 to 40°C raised the average thermal conductivity from 0.1448 to 0.1585 W/mK. The conducted tests on two varieties of nuts (Akbari and Kalleghoochi) demonstrated that the thermal conductivity of Kalleghoochi cultivar is lower than that of the Akbari cultivar at  $\alpha=0.05$ . Quadratic regression equations were developed depicting the effect of moisture content and temperature on thermal conductivity.

**Key Words:** Line heat source method, Thermal conductivity, Thermal conductivity probe, Unhulled pistachio nuts

(<sup>2</sup> )  
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25  
420 1357 62  
(1383 ) 1382  
( )  
(1980 )  
4  
( )  
1  
( )  
(2002 ) (1382

<sup>2</sup> Steady state  
<sup>3</sup> Transient state  
<sup>4</sup> Line heat source method

<sup>1</sup> Thermal conductivity

$$F(rn) = A - \ln(rn) + \frac{(rn)^2}{2} + \frac{(rn)^4}{8} + \dots \quad [4]$$

$$n = \frac{1}{2}(\alpha t)^{-1/2} \quad [5]$$

$$T - T_0 = \frac{q}{2\pi k} \left[ A - \ln(rn) \right] \quad [6]$$

$$T - T_0 = \frac{qA}{2\pi k} - \frac{q}{2\pi k} \ln\left(\frac{1}{2} r \alpha^{-1/2}\right) + \frac{q}{4\pi k} \ln(t) \quad [7]$$

$$s = \frac{Q}{4\pi k} \ln(t) \quad [8]$$

$$k = \frac{I^2 R}{4\pi S} \quad [8]$$

$$T - T_0 = \frac{q}{2\pi k} F(rn) \quad [3]$$

$$\frac{\partial T}{\partial t} = \alpha \left( \frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} \right) \quad [1]$$

$$T = \frac{Q}{2\pi k} \int_{\beta}^{\infty} \frac{\exp(-x^2) dx}{x} \quad [2]$$

$$\beta = \frac{r}{2\sqrt{\alpha t}} \quad [2]$$

$$T - T_0 = \frac{q}{2\pi k} F(rn) \quad [3]$$

$$k = \frac{I^2 R}{4\pi S} \quad [8]$$

$$s = \frac{Q}{4\pi k} \ln(t) \quad [8]$$

$$T - T_0 = \frac{q}{2\pi k} \left[ A - \ln(rn) \right] \quad [6]$$

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$$n = \frac{1}{2}(\alpha t)^{-1/2} \quad [5]$$

$$F(rn) = A - \ln(rn) + \frac{(rn)^2}{2} + \frac{(rn)^4}{8} + \dots \quad [4]$$

$$T - T_0 = \frac{q}{2\pi k} F(rn) \quad [3]$$

<sup>2</sup> Time correction factor

<sup>1</sup> Thermal conductivity probe

(<sup>2</sup>) (1) 7

:(1980 )

$$k = \frac{q}{4\pi} \left[ \ln \left( \frac{t_2 - t_0}{t_1 - t_0} \right) / (T_2 - T_1) \right] \quad [9]$$

( ) t<sub>0</sub>

)

(

) S410.1

( 10

130±3

.(1998 ) %51/8

)

(1975 ) (1991

%20/9 %27/2 %35/6 %42/3)

(1979 1969 )

62 (

) (1977 )

(1981 ) (2000

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(2002

4 5 2

)

10 6 (

20)

40 30 20 ( 40

.2

.1

(L/d)

<sup>1</sup> Long  
<sup>2</sup> Round

( )  
JUMO

<sup>1</sup>RTD

<sup>2</sup>

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8

100  
PT100

( 56)  
70

100 25

:(1980 )

$$(\Delta R)_{\max} = [5.64/\lambda + 6.8 \times 10^{-3} \sigma \lambda (\varepsilon - \eta)] \cdot e^{-0.01\lambda^2} \quad [10]$$

$\lambda$   $(\Delta R)_{\max}$

( )

$\sigma$  (L/d)

1

$\varepsilon$

1

$\eta$  ( $k_1/k_2$ )

(DC)

( $k_1/\alpha_1$ )

12

( $k_2/\alpha_2$ )

$\eta=5/25$   $\varepsilon=70$   $\sigma=0/5$  (L/d)=70

12

$$(\Delta R)_{\max} < \% (1 \times 10^{-18})$$

DM-9027T

0/01

0/7

) 1

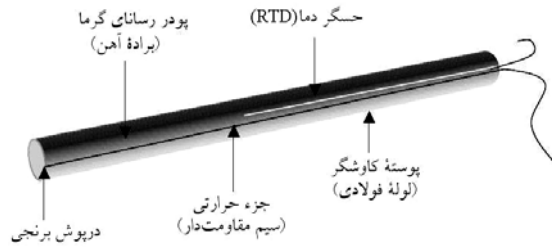
26/67

(

<sup>1</sup> Resistance temperature detector  
<sup>2</sup> Thin film

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3



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(T)

(3) (t)

(Kasra Electronics Inc.)

RTD

RS-232

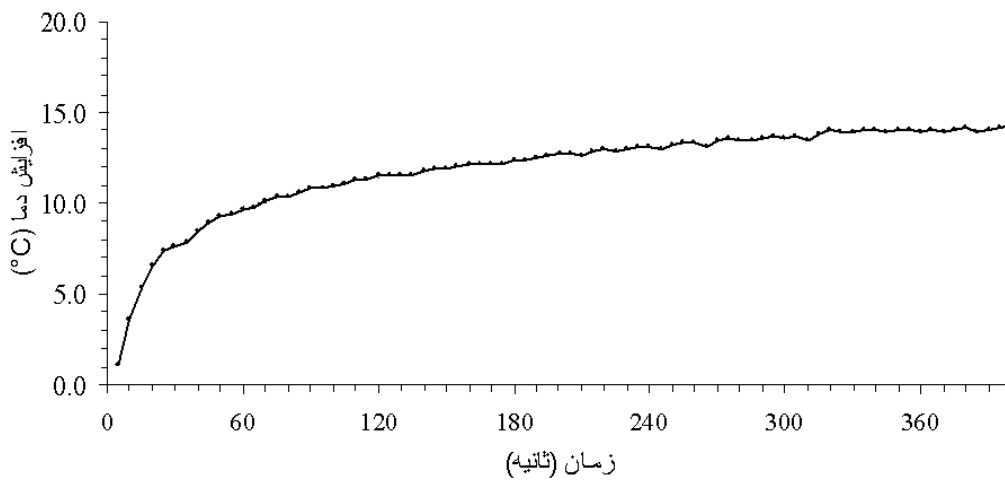
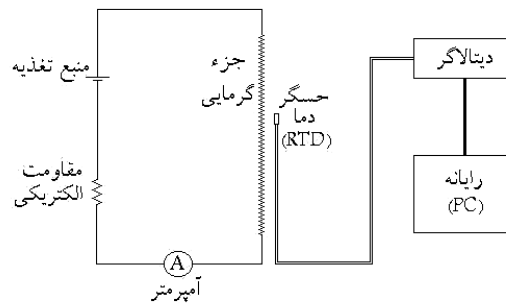
t

dt/dT (

( )

(4)

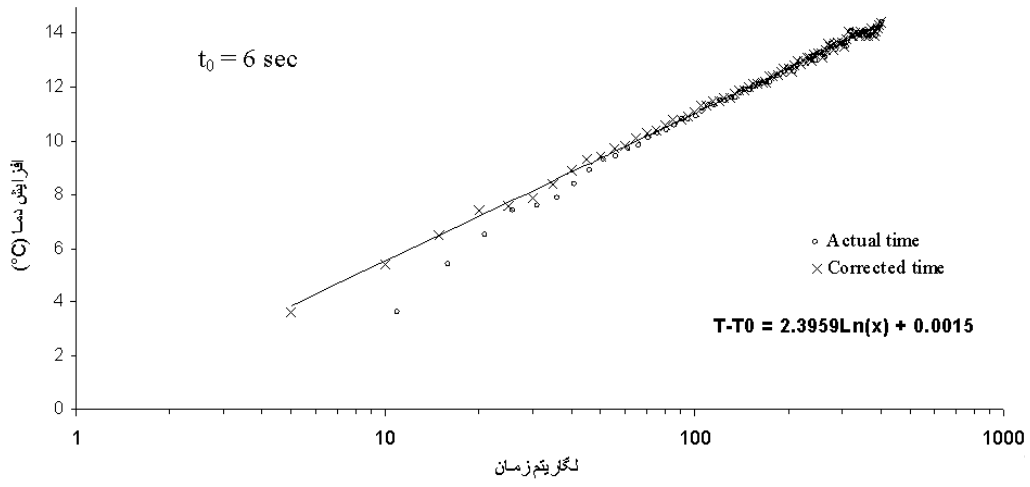
(2)



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18

45

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%5 %1

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6

			1
F	(10 <sup>4</sup> )		
7/04	0/209	1	
220/11	6/536	2	
0/82	0/024	2	×
	0/030	12	
			** *
		%1 %5	

20 %5 (LSD)

0/1769 W/m°C 40 30 30 20

%7 ( )

40 30 20 %11/6

(2 )

1973 )

1977 1975

1 (2003

2

)

(2002 2000

( )

%5

:(1382 )

) W/m°C

( 40 0/1993

(1980 )

<sup>1</sup> Cumin seed  
<sup>2</sup> Borage seeds



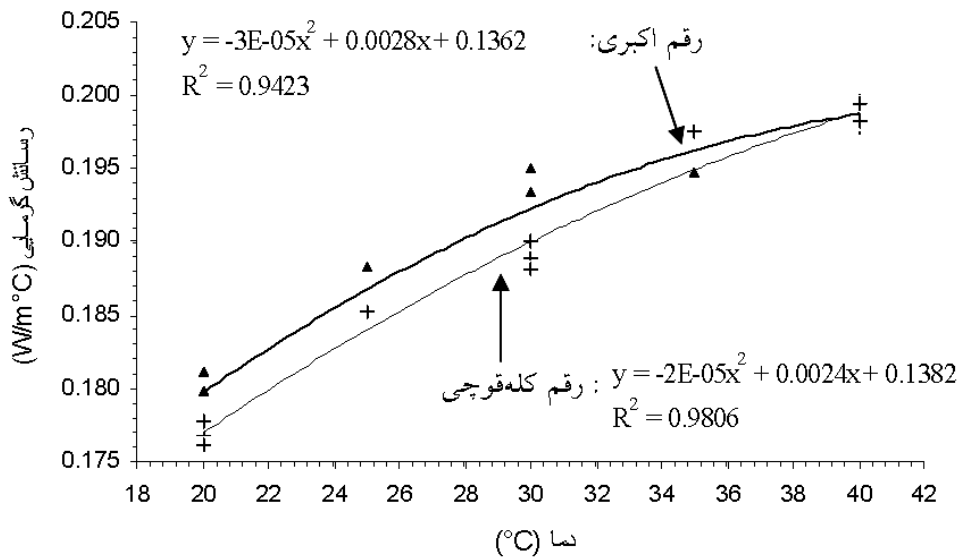
(W/m°C)			2
*			
**			(°C)
0/1782 <sup>C</sup>	0/1769 <sup>d</sup>	0/1795 <sup>d</sup>	20
0/1907 <sup>B</sup>	0/1891 <sup>c</sup>	0/1923 <sup>b</sup>	30
0/1989 <sup>A</sup>	0/1986 <sup>a</sup>	0/1993 <sup>a</sup>	40
0/1893	0/1882	0/1904	
(LSD% 5 = 0/0031)		LSD	*
0/0022	(α=%5)	LSD	**

)  
 (  
 %1  
 LSD (1379)  
 4  
 40 20  
 (%51/8 %20/9)  
 0/1904 W/m°C 0/1145 )  
 4 (.5 ) ( ) ( )  
 %5 (1975)  
 ) 2 1  
 (α=%5)  
 30 20 ) 5 3  
 (20/9)

<sup>1</sup>Midas

<sup>2</sup>Torch

	$R^2$	
$k = 0.001T + 0.162$	0/9091	[11]
$k = -3 \times 10^{-5}T^2 + 2/8 \times 10^{-3}T + 0.1362$	0/9423	[12]
$k = 0.0011T + 0.156$	0/9678	[13]
$k = -2 \times 10^{-5}T^2 + 2/4 \times 10^{-3}T + 0.1382$	0/9806	[14]



5

4

F	(10 <sup>4</sup> )		
859/32**	80/043	4	
74/42**	6/989	2	
2/90*	0/272	8	×
	0/094	30	

%1 %5

\*\* \*

**	(W/m°C)			5
	*(°C)			
	40	30	20	(%w.b.)
0/1904 <sup>A</sup>	0/1993 <sup>a</sup>	0/1923 <sup>b</sup>	0/1795 <sup>c</sup>	51/8
0/1694 <sup>B</sup>	0/1759 <sup>cd</sup>	0/1717 <sup>d</sup>	0/1606 <sup>e</sup>	42/3
0/1518 <sup>C</sup>	0/1591 <sup>e</sup>	0/1519 <sup>f</sup>	0/1444 <sup>g</sup>	35/6
0/1326 <sup>D</sup>	0/1381 <sup>h</sup>	0/1325 <sup>i</sup>	0/1272 <sup>j</sup>	27/2
0/1145 <sup>E</sup>	0/1198 <sup>k</sup>	0/1114 <sup>l</sup>	0/1124 <sup>l</sup>	20/9
0/1517	0/1585 <sup>A</sup>	0/1520 <sup>B</sup>	0/1448 <sup>C</sup>	
(LSD %5 = 0/0051)	LSD			*
0/0029	0/0023		LSD	**
				(α=%5)

16 15

0/108)

%12/8 %6/1

(0/155W/m°C

31/7 4/4

%50

(1379)

(R<sup>2</sup>=0/9065)

(R<sup>2</sup>=0/9869)

$$k = 0.0647 + 2/94 \times 10^{-5} T + 1/9 \times 10^{-7} M + 1/91 \times 10^{-8} TM \quad [15]$$

[16]

$$k = 0.0517 + 2 \times 10^{-5} T - 3/3 \times 10^{-5} T^2 + 1/49 \times 10^{-7} M - 1/6 \times 10^{-5} M^2 + 1/911 \times 10^{-8} TM$$

1979

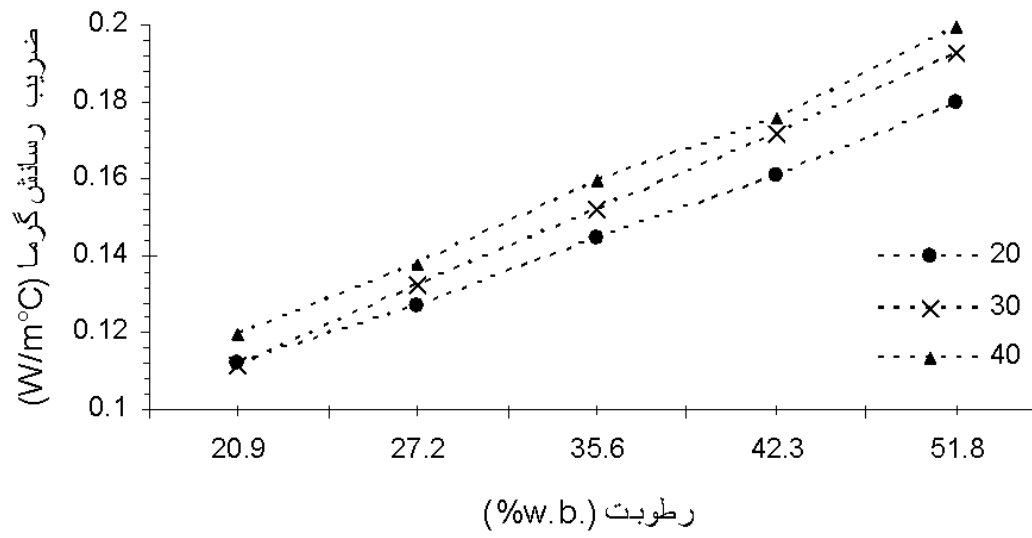
1975

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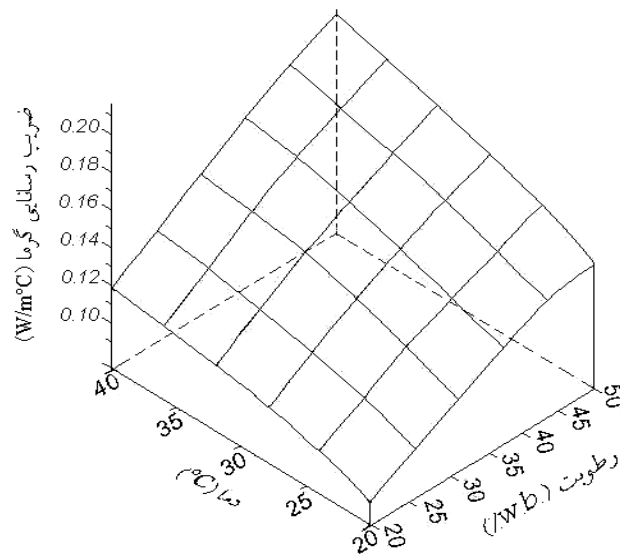
2000

1991

(2002



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	.1383
( )	.1382
( )	.1380
	.1379

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