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AN EXPERIMENTAL STUDY ON THE POOL BOILING HEAT TRANSFER COEFFICIENT OF MILK

UDC 536.22

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Abstract. *In this paper, the convective heat transfer coefficients for pool boiling of milk during khoa making in a stainless steel pot were investigated. A simple linear regression analysis was performed by using the experimental data in the Rohsenow correlation. The convective heat transfer coefficients were determined in the range of 283.02 to 783.97 W/m °C for the heat inputs varying from 240 to 360 W. The boiling heat transfer rate per unit surface area was predicted in the range of 2830.2 to 7839.7 W/m² °C at 10 °C excess temperature to the saturation temperature of the milk. The experimental error in terms of percent uncertainty was also calculated.*

Key words: *Milk, Khoa Making, Pool Boiling, Convective Heat Transfer Coefficient*

1. INTRODUCTION

India is the largest milk producing country in the world with an annual production of more than 91 million tons. About 7% of the total milk production is being utilized for making khoa due to its large scale consumption. Khoa is an important indigenous heat-coagulated partially-dehydrated milk product which forms an important base for preparation of various milk sweets. It is obtained by heat desiccation of a milk quantity to 65 to 70 percent milk solids without using any foreign ingredients [1], [2]. Khoa is a rich source of energy containing fat, protein, lactose and other minerals. Khoa making involves intensive heating during the desiccation process in order to stimulate evaporation of the large quantity of water present in the milk. The natural and boiling convection heat transfers are the major heat transfer mechanisms which occur during the heating process. Evaluation of the convective heat and mass transfer coefficient is necessary for the proper design of an evaporator for the given shape [3], [4].

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In the last seven decades, heat transfer under boiling has been investigated by many scientists worldwide. Many theoretical and empirical correlations have been proposed to estimate the heat transfer coefficients as well as the critical heat fluxes under boiling in different conditions [5]. A number of researchers have also studied different aspects of the nucleate pool boiling heat transfer with a variety of liquids. Constant values of the exponents in dimensionless numbers and a list of values of C_{sf} for some surface-fluid combinations were proposed by [6] that have been further extended by [7]. The Rohsenow pool boiling correlation has also been evaluated experimentally by many researchers at sub-atmospheric, atmospheric, or higher pressure [5], [7], [8], [9], [10], [11], [12]. Many varieties of boiling surfaces like plates [8], [13], [14], single tubes [15], wires [16], [17] and strips [18] have been used. The convective heat and mass transfer coefficient under pool boiling condition for sugarcane juice during preparation of jaggery were found to vary from 50.65 to 345.20 W/m^2 ^{o}C for heat inputs ranging from 160 to 340 watts [4]. An analysis of these earlier works shows that the main parameters that affect the heat transfer coefficient under pool boiling are heat flux, saturation pressure, thermo-physical properties of the working fluid, and some characteristics of the boiling surface materials like thermo-physical properties, thickness, surface finishing, micro-structure, dimensions, etc.

The lack of thermal design data or correlation including that of the heat transfer coefficient as a function of heat flux, thickness of heater wall and surface geometry, poses a serious problem in the design of the heat exchanger. This calls for the development of a simple and easily adoptable procedure to determine the heat transfer coefficient for heating milk under the pool boiling conditions. In the present study, an attempt has been made to experimentally investigate nucleate pool boiling of milk in a circular stainless steel pan for different heat inputs. A heat transfer analysis of the experimental data obtained for pool boiling of milk has been carried out by using the Rohsenow correlation for the surface boiling of liquids to determine the constants, the convective heat transfer coefficients and the heat flux.

2. Experimental Set-up and Procedure

The schematic diagram of the experimental set-up is shown in Fig. 1. It consists of a hot plate of 1000W capacity connected through a variac to control the rate of heating of the milk in a stainless steel pot of capacity 3.2 liters. The heat input was measured by a calibrated wattmeter (accuracy within ±0.5% of full scale value 1500 watts), having the least count of 1 watt. The calibrated copper-constantan thermocouples connected to a ten channel digital temperature indicator (least count of 0.1 ^{o}C, accuracy ± 0.1%, range of -50 to 200 ^{o}C) were used to measure the milk temperature (T_1), the surface temperature of the stainless steel pot at the bottom (T_2) and side (T_3) and room temperature (T_4). The milk surface temperature (T_5) has been measured by an infra-red thermometer (Raytek-MT4), having the least count of 0.2 ^{o}C with accuracy of ± 0.2% on a full scale range of -1 to 400 ^{o}C. The relative humidity (γ) and the temperature above the milk surface (T_6) have also been measured by a digital humidity/temperature meter (model Lutron-HT3006 HA). It had the least count of 0.1% relative humidity (accuracy within ± 3% on the full scale range of 10 to 95%) and 0.1 ^{o}C temperature (with accuracy of ±0.8 ^{o}C on the full scale range of 0 to 50 ^{o}C). The mass of water evaporated during heating of milk has been measured by using an electronic weighing balance of 6 kg capacity (Scaletech, model TJ-6000) with the least count of 0.1g with accuracy ± 2% on the full scale.

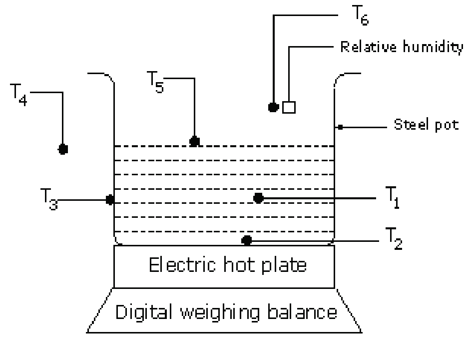

Fig. 1. Schematic diagram of experimental set-up

In order to determine the convective heat transfer coefficient of milk during khoa making under the pool boiling mode the following procedure has been employed:

The locally available fresh milk (obtained from a herd of 15 cows) is heated in a stainless steel cylindrical pot of 200 mm in diameter, 102 mm deep and 1.6 mm thick without any cover for different values of heat inputs ranging from 240 to 360 watts. Light manual stirring and scraping of milk are done by means of a Teflon scraper to avoid any scaling and burning of the product. The necessary data of temperature and the other parameters during heating of milk start to be recorded once the milk temperature becomes equal to 90 ^{o}C (i.e. pool boiling mode range) and are taken before the solidification of concentrated milk. Temperatures and relative humidity are measured at various locations as shown in Fig. 1. The mass of water evaporated during heating of milk for each set of observations is obtained by subtracting two consecutive readings in a given time interval. All the experimental parameters are recorded at every 10 min time interval. Different sets of milk heating are obtained by varying the input power supply from 240 to 360 watts to the electric hot plate with the help of variac. The experimental results for different sets of heating are reported in Tables 1-4.

Table 1. Observations for pool boiling of the milk in open pan for heat input=240 W at atmospheric pressure

Time interval (min)	T_1 (^{o}C)	T_2 (^{o}C)	T_3 (^{o}C)	T_4 (^{o}C)	T_5 (^{o}C)	T_6 (^{o}C)	γ (%)	w (g)	m_{evp} (g)
-	92.1	99.4	47.4	20.0	90.6	28.4	93.0	512.4	-
10	94.4	98.5	47.7	20.4	91.6	26.9	91.6	477.2	35.2
10	96.9	101.4	47.7	20.6	95.6	31.6	92.2	442.0	35.2
10	97.8	101.0	48.2	20.8	94.2	31.1	92.7	410.2	31.8
10	97.9	101.3	47.8	20.9	95.6	34.3	92.0	374.9	35.3
10	98.3	104.5	47.5	21.0	95.0	30.1	91.1	343.5	31.4
10	97.7	105.7	46.7	21.0	93.6	30.9	92.4	310.3	33.2

Table 2. Observations for pool boiling of the milk in open pan for heat input=280 W at atmospheric pressure

Time interval (min)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	γ (%)	w (g)	m_{evp} (g)
-	94.2	98.1	50.9	21.3	89.8	30.1	92.5	605.9	-
10	95.7	98.3	50.8	21.6	94.6	30.8	93.2	561.7	44.2
10	96.1	99.3	51.0	21.8	94.0	30.6	92.2	519.8	41.9
10	97.9	102.1	50.6	22.0	94.6	37.6	92.0	475.4	44.4
10	98.2	102.3	49.7	22.3	95.2	36.3	92.9	435.3	40.1
10	99.2	102.2	50.2	22.4	94.4	37.7	93.4	392.8	42.5
10	99.1	106.8	50.8	22.6	95.2	34.3	91.9	351.3	41.5
10	99.0	107.3	49.8	22.8	94.6	35.9	93.1	306.9	44.4

Table 3. Observations for pool boiling of the milk in open pan for heat input=320 W at atmospheric pressure

Time interval (min)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	γ (%)	w (g)	m_{evp} (g)
-	93.3	96.7	50.6	20.9	84.6	29.3	92.4	679.8	-
10	96.0	98.2	50.9	20.9	89.0	31.2	93.3	630.9	48.9
10	96.0	99.0	51.2	21.2	94.8	33.2	93.9	580.9	50.0
10	98.2	100.3	50.8	21.3	95.2	35.6	93.0	530.3	50.6
10	98.5	100.4	49.4	21.4	92.0	37.2	94.1	478.4	51.9
10	99.0	101.6	49.9	21.8	94.6	36.5	93.7	426.8	51.6
10	99.0	104.7	47.9	21.7	95.2	42.3	92.9	374.7	52.1
10	99.2	104.9	48.3	22.0	95.8	35.0	93.2	325.9	48.8
10	97.6	108.5	47.4	22.0	95.0	34.0	93.0	277.4	48.5

Table 4. Observations for pool boiling of the milk in open pan for heat input=360 W at atmospheric pressure

Time interval (min)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	γ (%)	w (g)	m_{evp} (g)
-	93.6	95.3	51.7	19.0	87.4	36.9	95.2	808.8	-
10	95.6	97.3	52.1	19.0	89.0	36.8	95.6	755.0	53.8
10	96.6	98.4	52.6	19.0	92.4	33.4	94.9	696.6	58.4
10	96.7	99.3	52.4	19.2	93.4	39.1	95.5	639.3	57.3
10	98.6	100.0	52.2	19.3	93.0	46.5	95.2	581.2	58.1
10	98.4	100.4	52.3	19.5	94.6	44.1	94.5	521.3	59.9
10	98.7	101.0	50.8	19.6	94.2	41.6	93.9	463.2	58.1
10	99.3	106.0	51.1	19.9	95.4	47.9	94.0	405.5	57.7
10	99.3	105.2	51.6	20.1	95.2	41.6	94.5	348.2	57.3
10	98.6	107.0	49.2	20.4	96.2	43.1	93.9	290.3	57.9

3. COMPUTATION PROCEDURE

The heat transfer analysis of the experimental data obtained for pool boiling of milk has been performed by using the most widely acknowledged correlation proposed by [6]. The correlation is expressed as

$$C_{pl}\left[\frac{T_s - T_{sat}}{h_{fg}\,\mathrm{Pr}^n}\right] = C_{sf}\left[\frac{q_{nucleate}}{\mu_l h_{fg}}\sqrt{\frac{\sigma}{g(\rho_l - \rho_v)}}\right]^{\frac{1}{3}} \tag{1}$$

Eq. (1) can also be written as

$$q_{nucleate} = \mu_l h_{fg}\left[\frac{g(\rho_l - \rho_v)}{\sigma}\right]^{1/2}\left[\frac{C_{pl}(T_s - T_{sat})}{C_{sf} h_{fg}\,\mathrm{Pr}^n}\right]^3 \tag{2}$$

The Prandtl number is calculated by using the following expression,

$$\mathrm{Pr} = \frac{\mu_l C_{pl}}{k_l} \tag{3}$$

The average convective heat and mass transfer coefficient can be given by

$$h = \frac{q_{nucleate}}{T_s - T_{sat}} \tag{4}$$

The Rate of water evaporated is determined by dividing Eq. (2) by enthalpy of vaporization and multiplying the area of pan

$$\dot{m}_{ev} = \frac{Q_{boiling}}{h_{fg}} = \frac{A q_{nucleate}}{h_{fg}} \tag{5}$$

Now with the help of Eq. (5), Eq. (2) can be rearranged as follows

$$C_{sf}\,\mathrm{Pr}^n = \frac{C_{pl}(T_s - T_{sat})}{h_{fg}}\left(\frac{A\mu_l}{\dot{m}_{ev}}\right)^{1/3}\left[\frac{g(\rho_l - \rho_v)}{\sigma}\right]^{1/6} \tag{6}$$

After substituting

$$K = \frac{C_{pl}(T_s - T_{sat})}{h_{fg}}\left(\frac{A\mu_l}{\dot{m}_{ev}}\right)^{1/3}\left[\frac{g(\rho_l - \rho_v)}{\sigma}\right]^{1/6}$$

Eq. (6) becomes

$$K = C_{sf}\,\mathrm{Pr}^n \tag{7}$$

Taking logarithm both sides of Eq. (7),

$$\log K = n \log \mathrm{Pr} + \log C_{sf} \tag{8}$$

The above equation represents the straight line in the following form,

$$y = mx + c \tag{9}$$

Where, $y = \log K$, $m = n$, $x = \log \Pr = \log(\mu_l C_{pl}/k_l)$ and $c = \log C_{sf}$

K in the above expression is calculated for various excess temperatures, (T_s -T_{sat}) recorded during the pool boiling experiments by using the thermal physical properties of milk. The corresponding values of x and y are also computed.

Thus the values of m and c in equation (9) are obtained by using the following formulae obtained by the linear regression method

$$m = \frac{N\sum xy - \sum x \sum y}{N\sum x^2 - \left(\sum x\right)^2} \tag{10}$$

$$c = \frac{\sum x^2 \sum y - \sum x \sum xy}{N\sum x^2 - \left(\sum x\right)^2} \tag{11}$$

The following expressions are used for calculating different physical properties of milk such as density ρ_l [19], viscosity μ_l [20], thermal conductivity k_l [21], specific heat C_{pl} [22], surface tension σ [23] and enthalpy of vaporization h_{fg} [24]:

$$\begin{aligned} \rho_l &= -0.2307\times10^{-2}T^2 - 0.2655T + 1040.51 \\ &-F(-0.478\times10^{-4}T^2 + 0.969\times10^{-2}\,T + 0.967) \end{aligned} \tag{12}$$

$$\ln \mu_l = 4.03\times10^{-5}T^2 - 2\times10^{-2}T + 0.827 \tag{13}$$

Where μ_l is in Pa.s $\times10^{-3}$

$$k_l = 0.356439\,\bar{X}_w + 0.223544 \tag{14}$$

$$C_{pl} = 2.976T + 3692 \tag{15}$$

$$\sigma = 1.8\times10^{-4}T^2 - 0.163T + 55.6 \tag{16}$$

Where σ is in N.m$^{-1}\times10^{-3}$

$$h_{fg} = (h_{fg} \text{ of water})\times\bar{X}_w \tag{17}$$

The physical properties of milk are determined at an average temperature in the time interval.

The experimental error is evaluated in terms of percent uncertainty (internal + external). The following two equations are used for internal uncertainty [25]:

$$U_I = \frac{\sqrt{sd_1^{\,2} + sd_2^{\,2} + \ldots sd_n^{\,2}}}{N_o} \tag{18}$$

Where sd is the standard deviation and is given as

$$sd = \sqrt{\frac{\sum (X-\bar{X})^2}{N}} \tag{19}$$

Where $X-\bar{X}$ is the deviation of observation from the mean and N are the number of sets.

The % internal uncertainty therefore has been determined using the following expression:

$$\% \text{ internal uncertainty} = (U_I/\text{mean of the total observations}) \times 100 \quad (20)$$

For external uncertainty, the least counts of all the instruments used in measuring the observation data have been taken.

4. Results and Discussion

The values of m and c have been evaluated from Eqs. (10) and (11) by using the experimental data from Tables 1 - 4. After evaluating m and c, the values of C_{sf} and n can be obtained as $C_{sf} = e^c$ and $n = m$. The values of C_{sf} and n are reported in Table 5. The convective heat transfer coefficients have been computed from Eq. (4) by using the values of C_{sf} and n for different values of heat inputs which are also given in Table 5.

Table 5. Values of the constants (C_{sf}, n) and h

Heat input (W)	C_{sf}	n [-]	h (W/m^2 ^{o} C)
240	0.964	1.240	283.02
280	0.935	1.317	417.69
320	0.886	1.345	578.33
360	0.867	1.473	783.97

Fig. 2 illustrates the variation of convective heat transfer coefficient for the different values of heat input. It varies from 283.02 to 783.97 W/m^2 ^{o} C for the given heat inputs ranging from 240 to 360 W. The increase in values of convective heat transfer coefficient with the increase in the heat input may be due to higher surface temperature of the pan and activation of more nucleation sites which causes rapid formation of the vapor bubbles at the pan-liquid surface.

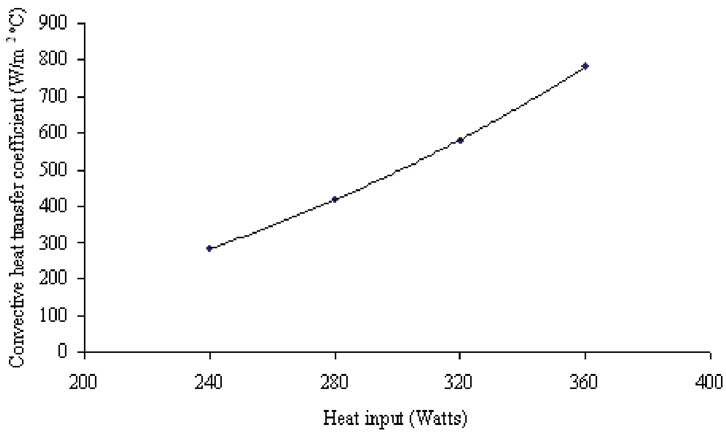

Fig. 2. Convective heat transfer coefficient variation with heat inputs

Fig. 3 illustrates the variation of the heat flux with excess temperature for different values of heat inputs. The general trend is that the heat flux rises exponentially with an increase in excess temperature as well as heat input. These results are in accordance with those reported in the Refs. [4], [26], [27], [28]. It is further observed that the heat transfer rate is increasing with excess temperature at low values of heat input. This is desired for khoa making to avoid any product burning or its sticking to the pot surface.

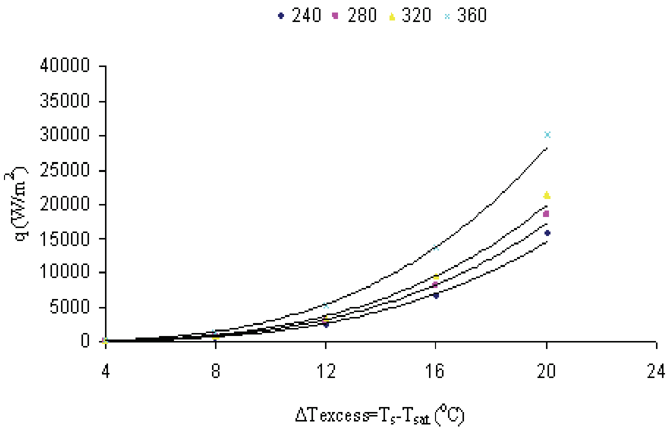

Fig. 3. Heat flux variation with excess temperature for different heat inputs

An analysis of the inaccuracies involved in the measurement of temperatures, mass evaporated and power input was carried out to obtain the experimental errors in terms of percent uncertainty (internal + external). It was estimated in the range of 7.27% to 14.02% and the different values of convective heat transfer coefficients are found to be within this range. The experimental percent uncertainties are reported in Table 6.

Table 6. Experimental uncertainties

Heat input (W)	Internal uncertainty (%)	External uncertainty (%)	Total uncertainty (%)
240	5.67	1.6	7.27
280	10.7	1.6	12.3
320	12.42	1.6	14.02
360	10.92	1.6	12.52

CONCLUSIONS

The convective heat transfer coefficients under pool boiling mode have been determined for milk using experimental data in the Rohsenow correlation by using a simple regression analysis. The values of the convective heat transfer coefficients are found to increase from 283.02 to 783.97 W/m ^{o} C for the heat inputs ranging from 240 to 360 W. This can be ascribed to a higher heating surface temperature which results in the formation of more active nucleation sites and rapid formation of the vapor bubbles at the pan-liquid surface. The variation of the heat flux with excess temperature of milk is also predicted since it is found to vary exponentially with increasing excess temperature as well as heat input. The experimental errors in terms of percent uncertainty are found in the range of 7.27 to 14.02%. The present study may be helpful in the design of an evaporator or for similar drying systems.

Nomenclature

A	Area of pan, m^2
C_{pl}	Specific heat, J/kg ^{o} C
C_{sf}	Experimental constant depending on surface-fluid combination
F	Fat content %
g	Gravitational acceleration, m/s^2
h	Convective heat and mass transfer coefficient, W/m^2 ^{o} C
h_{fg}	Enthalpy of vaporization, J/kg
k_l	Thermal conductivity of milk, W/m ^{o} C
m_{ev}	Mass evaporated, kg
$\dot{m}_{ev}$	Rate of mass evaporated, kg/s
N	Number of observations in each set of heat input
n	Fluid-dependent experimental constant
Pr	Prandtl number
$q_{nucleate}$	Nucleate boiling heat flux, W/m^2
T	Temperature, ^{o} C
T_s	Average surface temperature, ^{o} C
T_{sat}	Saturation temperature, ^{o} C
w	Weight of milk, g
$\bar{X}_w$	Average water content % in time interval
μ_l	Viscosity of milk, kg/m.s
ρ_l	Density of milk, kg/m^3
ρ_v	Density of vapor, kg/m^3
σ	Surface tension of milk, N/m

REFERENCES

1. Rajarajan, G., Kumar, C.N., Elango, A., 2007, Distribution pattern of moulds in air and khoa samples collected from different sections of khoa plants, Indian Journal of Dairy Science, Vol. 60, No. 2, pp. 133-135.
2. Kumar, M., Prakash, O., Kasana, K.S., Dabur, R.S., January 2010, Technological advancement in khoa making, Indian Dairyman, Vol. 62, No.1, pp. 64-70.
3. Tiwari, G.N., Prakash, O., Kumar, S., 2004, Evaluation of convective heat and mass transfer for pool boiling of sugarcane juice, Energy Conversion and Management, Vol. 45, pp. 171-179.
4. Das, S.K., 2006, Process heat transfer, Narosa Publishing House, New Delhi.
5. Pioro, I.L., 1999, Experimental evaluation of constants for the Rohsenow pool boiling correlation, International J Heat Mass Transfer, Vol. 42, pp. 2003-2013.
6. Rohsenow, W.M., 1952, A method of correlating heat transfer data for surface boiling of liquids, Trans ASME, Vol. 74, pp. 969-976.
7. Vachon, R.I., Nix, G.H., Tanger, G.E., 1968, Evaluation of constants for Rohsenow pool boiling correlation, Journal of Heat Transfer, Vol. 90, pp. 239-247.
8. Berenson, P.J., 1962, Experiments on pool boiling heat transfer, International J Heat Mass Transfer, Vol. 5, pp. 985-999.
9. Labuntsov, D.A. 1972, Heat transfer problems with nucleate boiling of liquids, Thermal Engineering, , Vol. 9, pp. 21-28.

10. Sauer, J.H.J., Medrow, R.A., Sinnarwalla, A.M., 1975, Effects of surface condition on nucleate boiling of refrigerant-11. ASHRAE Transactions, Vol. 81, No.2, pp. 274-280.
11. Lal, G., Verma, R.D., 1987, Evaluation of constants for Rohsenow pool boiling correlation for ghee, Indian J. Dairy Sci., Vol. 40, No. 4, pp. 431-434.
12. Jabardo, J.M.S., Silva, E.F.D., Ribatski, G., Barros, S.F.D., 2004, Evaluation of the Rohsenow correlation through experimental pool boiling of halocarbon refrigerants on cylindrical surfaces. J. of the Braz. Soc. of Mech. Sci. and Eng., Vol. 26, No. 2, pp.218-230.
13. Cichelly, M., Bronilla, C., 1945, Heat transfer to liquids under pressure, Trans AIChE, Vol. 41, pp. 755-787.
14. Clark, H.B., Strenge, P.S., Westwater, J.W., 1959, Active sites of nucleate boiling, Chem Eng Prog Symp Ser, Vol. 55, No.29, pp.103-110.
15. Cryder, D.S., Finalbargo, A.C., 1937, Heat transmission from metal surfaces to boiling liquids. Effect of temperature of liquid on liquid film coefficient, Trans AIChE, Vol. 50, pp. 346-362.
16. Addoms, J.N., 1948, Heat transfer at high rates to water boiling outside cylinders, DSC Thesis, Chemical Engineering Department, Massachusetts Institute of Technology MA.
17. Farber, E.A., Scorah, E.L., 1948, Heat transfer to water boiling under pressure, Trans ASME, Vol. 70, pp.369-384.
18. Young, R.K., Hammel, R.L., 1965, Higher coefficients for heat transfer with nucleate boiling, Chem Eng Prog Symp Ser, Vol. 61, No.59, pp.264-270.
19. Bertsch, A.J., Bimbenet, J.J., Cerf, O., 1982, Density of milk and creams between 65 and 140 ^{o}C, Lait, Vol. 62, pp. 250-264.
20. Bertsch, A.J., Cerf, O., 1983, Dynamic viscosities of milk and cream from 70 to 135 ^{o}C, Journal of Dairy Research, Vol. 50, pp. 193-200.
21. Murdia, L.K., Verma, R.D., 1982, Thermal conductivity of liquid dairy products by line heat source method, Journal Institution of Engineers (India), Vol. 63, pp. 30-33.
22. Bertsch, A.J., 1982, The specific heat capacity of whole and skimmed milk between 50 and 140 ^{o}C, Lait, Vol. 62, pp.265-275.
23. Bertsch, A.J., 1983, Surface tension of whole and skim milk between 18 and 135 ^{o}C, Journal of Dairy Research, Vol. 50, pp. 259-267.
24. Cengel, Y.A. 2002, Heat transfer-a practical approach, Tata McGraw-Hill Publishing Company Limited, New Delhi.
25. Akpinar, E.K., 2004, Experimental investigation of convective heat transfer coefficient of various agricultural products under open sun drying, International journal of green energy, Vol. 1, No. 4, pp. 429-440.
26. Incropera, F.P, Dewitt, D.P., 1990, Fundamentals of heat and mass transfer, 3rd ed., John Willey & Sons, USA.
27. Bejan, A. and Kraus, A.D., 2003, Heat Transfer Handbook, John Willey & Sons, USA, pp. 654.
28. Ozdemir, M, Pehlivan, H., 2008, Prediction of the boiling temperature and heat flux in sugar- water solutions under pool boiling conditions, Heat Mass Transfer, Vol. 44, pp. 827-833.

JEDNO EKSPERIMENTALNO PROUČAVANJE PRENOSA PRENOSA KOEFICIJENTA TOPLOTE KLJUČANJA MLEKA

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Ovaj rad ispituje koeficijent provođenja toplote za ključanje mleka tokom pravljenja koe[·] *u sudu od nerđajućeg čelika. Prosta linearna regresiona analaliza je obavljena na osnovu eksperimentalnih podataka uz pomoć Rošenove korelacije. Koeficijenti provođenja toplote su određeni u opsegu od 283.02 do 783.97 W/m o C za ulaze toplote u rasponu od 240 do 360 W. Stota prenosa toplote ključanja po jedinici površi predviđena je u opsegu od 2830.2 do 7839.7 W/m2 o C na 10 o C viška temperature do temperature zasićenja mleka. Uračunata je i eksperimentalna greška u smislu procentualne neizvesnosti.*

Ključne reči: *mleko, pravljenje koe, ključanje, koeficijent provodnog prenosa toplote*

[·] Vrsta pakiskatnsko-indijskog mlečnog proizvoda, prim. lek.