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ENERGY REQUIREMENTS IN MANUFACTURE OF KHOA UNDER CLOSED CONDITION

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ABSTRACT

Khoa making is a time consuming and energy intensive process involving continuous removal of water which requires large amount of heat. This research paper reports the results for the energy required during heating of milk for manufacture of khoa in aluminum and stainless steel pots under closed conditions. Various experiments were conducted for different heat inputs varying from 240 watts to 360 watts. During heating of milk the evaporated water condensed at the inner surface of the condensing cover was collected as fresh water. The average energy used for the evaporation of per gram of water during khoa making in aluminum and stainless steel pots found to be 6.85837 kJ and 8.28701 kJ respectively. Further, the actual amount of energy consumed for the evaporation of water during heating of milk in both the pots have also been evaluated which were observed to decrease with the increase in heat inputs. The information can be used to reduce energy utilization for khoa making in rural India.

Keywords: Khoa; Khoa making; milk heating under closed condition.

1. INTRODUCTION

Today, India has emerged as the largest milk producing country in the world with an annual production of more than 91 million tonnes [1]. India is producing 15 percent of total milk production in the world with an annual rate of growth of about 5 percent [2]. It has been estimated that nearly 7% of the total milk production is being utilized for making khoa due to its large scale consumption [3]. Khoa is an important indigenous heat coagulated, partially dehydrated milk product which is very popular in large section of Indian population throughout the country. Khoa has considerable economic and dietary importance to Indian population. It forms an important base for preparation of milk sweets which are an integral part of Indian food heritage. It is obtained by heat desiccation of whole milk to 65 to 70 percent milk solids without the addition of any foreign ingredients. For khoa making, generally traditional method is followed in which milk is heated in an open pan over non smoky fire and continuously it is stirred and scraped with the help of a scraper to avoid the scorching of milk solids sticking to the pan. It is estimated that six lakh tonnes of khoa is being prepared annually, mostly in private and unorganized sectors of India [4-6].

Khoa making involves intensive heating during the desiccation process with an aim of evaporating the large quantity of water present in the milk. Thus, khoa making process consumes a large amount of heat because of continuous removal of water for long periods of time. The energy used for khoa making is generally derived from non-renewable sources. The price of fossil fuel is increasing which in turn increases the processing expenses and hence the product cost. Agrawala et al. [7] reported that 6.802 kg of steam energy is required per kg of khoa production. Verma and Girdhari Lal [8] have estimated that 1.2 to 1.35 kg of steam energy is required per kg of milk to convert it into khoa.

In the case of conventional method of khoa making the evaporated water is lost in the atmosphere. If the evaporated mass of water is allowed to condense, then the condensate can be reutilized for other uses. Thus, the objective of the present study is to evaluate energy requirement during khoa making in aluminum and stainless steel pots under closed conditions. Efforts have been made to collect the condensate. This study will be very useful in making the energy users conscious about the energy consumption and losses during khoa making under closed conditions. This will also help in selecting suitable metallic pot and thus to reduce the energy utilization for khoa making.

2. MATERIALS AND METHODS

2.1 Experimental set-up details and observations

The schematic diagram and a photograph of the experimental set-up under closed condition are shown in Figures 1 and 2 respectively. It consists of a hot plate (178 mm in diameter) of 1000W capacity connected through a variac to control the rate of heating of the milk in a pot of capacity 3.2 liters. The pot was closed by a vertical cylinder (192 mm high) covered by a hemi-spherical shaped condensing cover (60 mm high) brazed at its top. Both the vertical cylinder and the condensing cover were made of 24 gauge thick galvanized sheet. An arrangement for collection of the condensate was made by welding a copper channel inside the condensing cover around it. The heat input was measured by a calibrated wattmeter (accuracy within ±0.5% of full scale value 1500 watts), having a least count of 1 watt. 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 a least count of 0.1g with an accuracy ± 2% on the full scale.

In the present study, the following temperature ranges were considered: natural convection boiling (sensible heating) is up to <90^{o}C (i.e. 20-90 ^{o}C) and pool boiling starts at 90-95 ^oC (i.e. >90^{o}C) [9, 10, 11, and 12]. It is important to mention here that the distillate output during heating of milk under closed condition was observed at temperature >90 °C. This range is termed as pool or nucleate boiling condition which is preferred for khoa making. In order to compare the heating performance of aluminum and stainless steel pots during khoa making under closed conditions the size of the pots is kept same i.e. 200 mm in diameter, 102 mm deep and 1.6 mm thick.

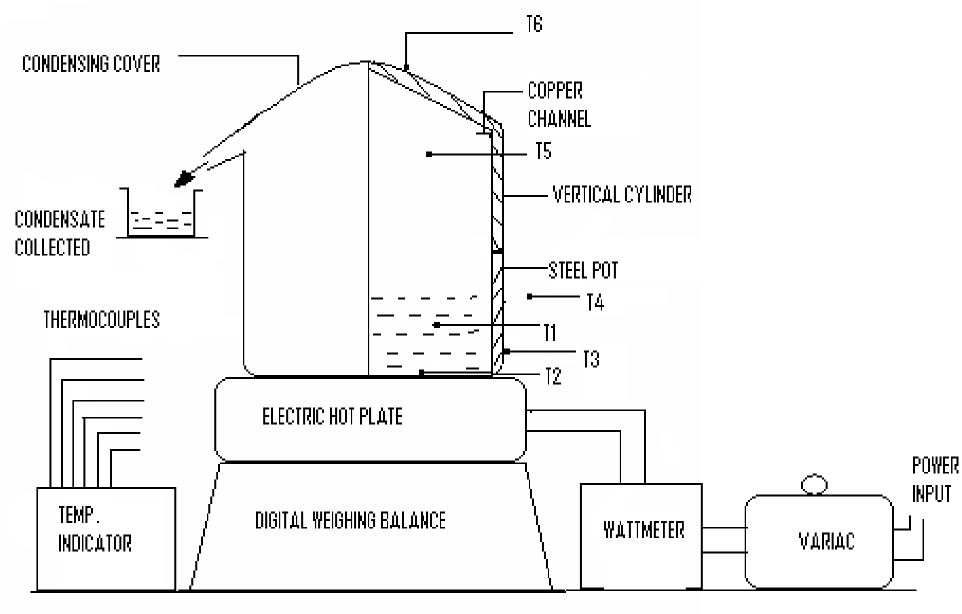

Fig. 1: Schematic diagram of experimental set up.

Fig. 2: A photographic view of experimental set up.

2.2 Experimental procedure

In order to determine the energy requirements for khoa making in aluminum and stainless steel pots under closed conditions, the following procedure is employed:

1. Locally available fresh milk (obtained from a herd of 15 cows) was heated for different values of heat inputs varying from 240 watts to 360 watts. The experiments follow a path of increasing heat inputs. For each run of the test, a fresh milk sample of constant mass (i.e. 935 g) was taken from the same herd of cows. But, at higher heat input (i.e. 360 watts) the quantity of milk sample was reduced to 735g because of the spillover due to high rate of bubble formation.
2. The data of mass evaporated and other parameters were recorded after every 10 minutes time interval. The mass evaporated during heating of milk was obtained by subtracting two consecutive readings in the given time interval.
3. By varying the input power supply from 240 watts to 360 watts to the electric hot plate with the help of the variac different sets of heating of milk were obtained for aluminum and stainless steel pots. The total processing time and the mass of water evaporated for the given range of heat inputs for heating of milk in aluminum and stainless steel pots are reported in Table 1.
4. The experimental data were recorded for natural convection and pool boiling phases before the solidification of concentrated milk.

2.3 Measurement of processing time and computation of energy requirement

The processing time was recorded by a stopwatch from the moment, the power input was supplied to the milk, and it was considered before the solidification of the concentrated milk.

Energy consumption during khoa making was computed separately for sensible heating and pool boiling phases and then summed up to obtain the total energy consumption.

The actual amount of energy consumed during manufacture of khoa was calculated on the basis of the values of overall heat transfer coefficients. The overall heat transfer coefficients were determined by taking the values of the convective heat transfer coefficients (h_c). The evaluations of the convective heat transfer coefficients during heating of milk for khoa making in aluminum and stainless steel pots are reported elsewhere [9, 11].

3. RESULTS AND DISCUSSION

The total energy requirements during heating of milk for khoa making in aluminum and stainless steel pots under closed conditions have been estimated which are given in Tables 1 & 2 respectively.

Table 1: Energy requirements for khoa making in an aluminum pot under closed condition at different heat inputs

Heat input (W)	Total time (min)	Total energy input (kJ)	Total mass evaporated (g)	Energy requirement per gram of mass evaporated (kJ/g)
240	250	3600	438.7	8.20606
280	200	3360	476.5	7.05142
320	160	3072	485.2	6.33141
360	140	3024	517.4	5.84461

Table 2: Energy requirements for khoa making in a stainless steel pot under closed condition at different heat inputs

Heat input (W)	Total time (min)	Total energy input (kJ)	Total mass evaporated (g)	Energy requirement per gram of mass evaporated (kJ/g)
240	260	3744	387.3	9.66692
280	200	3360	393.4	8.54092
320	170	3264	413.9	7.88596
360	150	3240	459.3	7.05421

It is observed from Tables 1 & 2 that the energy required for per gram of mass evaporated during heating of milk in both the pots decrease with an increase in heat inputs from 240 watts to 360 watts. It is found to decrease about 40.40% and 37.04% in the case of aluminum and stainless steel pots respectively for the given range of heat inputs.

In order to compare the heating performance of aluminum and stainless steel pots the average values of the energy required per gram mass of water evaporated from milk have also been calculated which are reported in Table 3.

Table 3: Average energy required for khoa making in aluminum and stainless steel pots under closed conditions

S.NO.	Cases	Average Energy (kJ/g)
1	Aluminum pot under closed condition	6.85837
2	Stainless steel pot under closed condition	8.28701

From Table 3, it can be seen that the energy required for the removal of water from the milk is less in the case of milk heating in an aluminum pan. It is found that the energy requirements for the evaporation of per gram mass of water during khoa making in an aluminum pot is 1.42864 kJ less than in a stainless steel pot. This means that using an aluminum pot instead of a stainless steel pot for khoa making under closed condition will save 17.24% amount of energy for each gram of water evaporated.

The actual thermal energy used for khoa making under closed conditions during heating of milk in aluminum and stainless steel pots at different rate of heat inputs are also calculated which are presented in Table 4 & 5 respectively.

Table 4: Actual amount of energy required for khoa making in an aluminum pot under closed condition

Heat input (W)	Total energy input (kJ)	Pool boiling		Actual energy required, Q_a (kJ)
	(sensible heating) + (pool boiling)	h_c (W/m^2 ^{o}C)	U (W/m^2 ^{o}C)	
240	(576)+(3024)=3600	186.32	161.00	41.59
280	(504)+(2856)=3360	249.85	206.34	37.35
320	(576)+(2496)=3072	343.04	266.03	34.11
360	(432)+(2592)=3024	567.56	383.76	36.05

Table 5: Actual amount of energy required for khoa making in a stainless steel pot under closed condition

Heat input (W)	Total energy input (kJ)	Pool boiling		Actual energy required, Q_a (kJ)
	(sensible heating) + (pool boiling)	h_c (W/m^2 ^{o}C)	U (W/m^2 ^{o}C)	
240	(720)+(3024)=3744	160.51	51.11	21.88
280	(504)+(2856)=3360	205.25	54.93	12.43
320	(768)+(2496)=3264	285.06	59.38	25.75
360	(648)+(2592)=3240	374.52	62.49	12.72

From Tables 4 & 5, it can be seen that the actual amount of energy consumption during khoa making in an aluminum pot is relatively more than in the case of a stainless steel pot for the given range of heat inputs. It can also be seen that the actual amount of energy consumed during khoa making in both the pots decreases with an increase in heat inputs. It means the actual amount of energy consumption decreases at high rate of heat inputs, thus energy losses increase.

CONCLUSIONS

The following important results can be drawn from the present research work in which the energy requirements during heating of milk for khoa making in aluminum and stainless steel pots under closed condition have been estimated.

1. The amount of energy required per gram mass evaporated during heating of milk in aluminum and stainless steel pots were found 6.85837 kJ and 8.28701 kJ respectively.
2. An aluminum pot would save 17.24% amount of energy for each gram of water evaporated in comparison to a stainless steel pot.
3. The actual amount of energy consumed during heating of milk for khoa making in aluminum and stainless steel pots decreases with an increase in given heat inputs. It is concluded that the actual energy consumption during heating of milk under closed condition decreases with an increase in heat inputs, thus energy losses increase. So, it will be advisable to make khoa at low heat inputs.

Thus, on the basis of energy consumption, it is stated that using an aluminum pot for khoa making at low heat input is advantageous and can help in saving the energy in rural India.

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