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Selection of thermo fluid in double jacketed vat for Basundi manufacture

Lakhwinder Singh, Gopika Talwar, Amandeep Sharma and Narender Kumar

Abstract
Indian dairy industry is dominated by small and unorganized dairy processing units. Processing of milk products at small scale is labour intensive resulting in non-efficient use of energy and non-uniform product quality. At small scale milk processing require high investment and operation of boiler is not feasible. Therefore study was undertaken to modify an existing double jacketed vat for thermo fluid heating system. Two wet coil heaters of capacity 3 kW each were fitted in cavity of 4cm thickness. The shape of modified vat was frustum of cone with 3mm outer mild steel sheet and 3mm stainless sheet for inner bin. An agitator was employed with three blades for scrapping of the product manufactured. Two oils were tested (paraffin and silicon oil) for heat transfer medium in cavity of modified unit. Properties of thermo fluid like boiling point specific heat, rate of temperature rise were studied and paraffin oil was found to be more suitable thermo fluid. Silicon oil was observed to have lower smoke point of 166 º C so was not used for manufacture of heat desiccated product. Different volumes (10, 20 and 30 kg) of milk was taken to vat to study the effect of capacity, temperature distribution and it was found that maximum heat transfer. With 30 kg capacity and 20 litres of paraffin oil heat desiccated product basundi was prepared in modified vat and evaluated for colour and sensory analysis. Basundi manufactured by modified vat scored 7.3 in overall acceptability to 7.7 of control sample. Total solids of basundi were calculated as 42% and in comparison to control sample, basundi prepared in MDJV had lower "l" values and higher 'a' and 'b' value.

Keywords: thermo fluids, paraffin oil, silicon oil, traditional dairy products, basundi

Introduction
India is the largestmilk producer in the world, with an average production of 155.5 million tonnes in the year 2015-16 (Anon, 2016). Out of this about, 50- 55% of the total milk production is converted into traditional milk products using processes such as heat and acid coagulation, heat desiccation and fermentation (Dairy India, 2007). The current method for the manufacture of traditional dairy products is based on the techniques that remained unchanged over ages.

One of the major constraint for unhygienic and non-uniform quality of product is unavailability of equipment for small scale processing. The Indian process equipment manufacturing companies and R&D institutions have mostly focused on developing equipment's for large scale manufacturing. For small scale product manufacturer, use of boiler is not feasible as it requires high initial investment, regulatory clearance and technical manufacturer for its operation. (Patil and Pal 2005) [9]. One such alternate to steam is thermo fluids which can be used in small scale dairy industry.

Thermo fluids are mainly used in high temperature process applications where the optimum bulk fluid operating temperatures ranged from 150ºC to 400ºC are safer and more efficient than steam, electrical, or direct fire heating methods. To meet the requirement of small and medium entrepreneurs, thermo fluid heating system is most suitable. (NIL 2010) [8].

Thermo fluids are used in a variety of applications and industries where high temperatures are required. Some products are used in aerospace, automotive, marine or military applications. Others are used with combustion engines, processing equipment, compressors, piston pumps, gears and final drives. Thermal oils are also be used in food, beverage and pharmaceutical applications, but its use in dairy industry is scanty.

Thermal oils can be categorized by chemical structure into three primary groups: synthetics, non- synthetics and silicones (NIL, 2010) [7].

Synthetics are able to obtain safe operating temperatures in the region of 400ºC, whereas non-synthetics are only thermally stable up to a maximum temperature of 300ºC. Silicone and glycerol fluids, are primarily used in specialized heating applications.

As per guidelines, in food process industry thermal oil was used for transferring heat to cooking oil used to fry potato chips in temperature controlled fryers.(NIL 2010) [8] It was also chemically acceptable for use as a heat transfer fluid in plants operating under the Federal Meat and Poultry Inspection Program. It was recommended for medium pressure heat transfer system used for food processing, canning, and bottling. Mineral oils can be part or all of what is used as a "hot oil" for heat transfer (RADCO, 2017) [12].

Thermo fluid has found application in food and dairy industry as heating medium oil. Thermal oil was used in heating of food extruder and in deodorization process. Thermal oil was used to control the temperature of extrusion process owing to its high heat transfer rate and ability to attain high temperature at atmospheric pressure, thermo fluids can find its application in manufacture of traditional dairy products where, for desiccation high temperature is required and specially at small scale where using boiler for generating hot water is not an feasible option. Out of traditional dairy products, basundi is one such product where desiccation occure to take concentration of milk to 2.5 times. It was anticipated in this research that thermo fluid could be used as heat transfer medium for basundi making at small scale.

Many researchers have conducted research on mechanization of Basundi making like; a conical process vat for basundi manufacture developed by Ranjeet *et al* (2003). Basundi prepared in conical process vat were good in body and texture, appearance and overall acceptability for processing time 80 to 100 minutes. Shah *et al* (2004) [13] mechanized basundi at Gujrat Agriculture University by using batch type stainless steel SSHE and the product was compared with conventional method in sensory and rheological profile with color and score. Product was uniform and consistent in all batches. Patel *et al* (2005) [9] made Basundi by open pan concentration using steam jacketed kettle and products were evaluated for their proximate composition, physico-chemical properties, sensory attributes and their heat transfer behavior at different operating conditions. Patel (1999) carried out systematic studies to develop standardize procedure for making basundi on commercial scale

Patel (2006) [10] developed continuous basundi making machine based on the principle of TSSHE. Continuous basundi making machine was developed by Patel *et al (*2007) [11] and energy efficiency of machine was measured. Kumar *et al* (2005) studied the performance evaluation of two stage thin film scraped surface heat exchanger for manufacture of khoa using low fat milk and it was observed that due to problem of scaling khoa could not be made from milk having 4% fat.

All above researches have been conducted on shape of vat used for basundi making or for material selection of the vat using steam as the heat transfer medium. Scanty research have been reported on use of thermo fluids as heat transfer medium = for batch type system for basundi making.

Thermal oils (thermo fluids) allow the use of low pressure heat transfer systems to achieve high temperatures which would otherwise have necessitated high pressure steam systems.Such type of system will not require boiler and initial capital investment will be low to start up any small dairy processing unit. Many researches have been done in the mechanization of batch type equipment's for manufacture of heat desiccated products using lpg and other heat sources so in view of the above justification, idea was conceived to manufacture a double jacketed vat using new heating medium i.e. thermo fluid.

Material and Methods

Selection of thermo fluid

Two thermo fluids i.e. Paraffin oil and silicon oil were purchased from Central Drug House Pvt. Ltd., New Delhi. The selection of two thermo fluids were made on the basis of specific heat, increase in volume, boiling point and smoking point. Various preliminary trials were conducted with paraffin oil and silicon oil to observe boiling point, increase in volume, and smoke point in two different heating systems i.e. Coil heating and gas heating to decide upon which heat source will help in attaining higher temperature in lesser time. Specific heat values for both the thermo fluids were obtained from literature. Specific heat value indicates that how much heat is required to raise the temperature of oil by one degree celcius.

Various trials were conducted with paraffin oil and silicon oil to observe boiling point, increase in volume, and smoke point in various conditions. Time Temperature distribution was also studied on gas heating and coil heating.

Preliminary trials of heating thermo fluid on gas

To determine the time temperature behavior of thermo fluids one litre each of oil was heated in a vessel and heated on a gas (full flame). Temperature of oil was observed after each minute to note down the rate of temperature increase. When maximum temperature was reached then gas was switched off and temperature stability of oil was observed by noting the decrease in temperature with time.

Trials of heating thermo fluid on coil

To observe the difference in heating on LPG and electric heating one liter of thermos fluid was taken in a vessel and heating was done on electric coil. The temperature distribution with time was observed. The maximum temperature attained on coil heating was observed.

To study temperature stability of thermo fluid

For the manufacture of heat desiccated milk products, heat must be maintained by the heat transfer medium for a longer period of time. It is important for heat transfer medium to remain at high temperature even if electrical connection is switched off.

As two oils i.e. paraffin oil and silicon oil were under study, both oils were tested for temperature (heat) stability. To check for the heat stability paraffin and silicon oil were heated on electrical or gas system to attain maximum temperature. At a point when maximum temperature is attained the electrical was switched off and temperature reading of oil at cooling off stage was taken at an interval of 5 minutes. Rate of temperature decrease per unit time was noted down. Increase in volume of thermo fluid on heating and smoke point was determines as per method mentioned by Singh and Talwar (2018).

Increase of volume of thermo fluid on heating

The existing double jacketed vat was modified for a thermo fluid heating system and it consisted of a cavity for thermo fluid so, it was important to know its increase in volume on heating. This helped in designing the head space of double jacketed vat cavity where thermo fluid was to be filled.

To determine increase in volume one liter of silicon oil and paraffin oil were heated to their respective maximum temperature. Volume of oil was measured again after
Increase in volume was calculated as follows

$\Delta V = V_2 - V_1$

Where, ΔV = increase in volume (ml)
V_1= initial volume of oil before heating (ml)
V_2=Final volume of oil after attaining maximum temperature (ml).

Determination of smoke point
As the temperature of thermo fluid is very high at atmospheric pressure so it was important to determine smoke point of oils under study.
To determine the smoke point one liter of oil was taken in vessel and was heated. Temperature of oil was observed at an interval of five minutes. The temperature at which fumes started rising from oil and sustained was noted down as smoke point. Thermo fluid having higher smoke point was found to be desirable because as fumes rise from oil, they may come in contact with upper surface of milk in the vat, this contact would have given milk product an off flavor which is undesirable

Modification of existing unit
For using thermo fluid for basundi making, an existing vat was modified with required design changes. Changes in design of double jacketed vat included increasing the size of cavity, capacity of cavity, heater arrangement, agitator design and measuring and controlling units and is given in research work presented by Singh and Talwar (2018).
Double jacketed vat had a wall thickness of 4 cm with annular spacing of 5cm having total volume of 30 liters. The inner surface of vat was fabricated from 3 mm thick SS 304 grade SS plate the outer surface of vat was fabricated from 2 mm mild steel plate. A vent of mm was provided on top of thickness of cavity for outlet of fumes. The technical drawing of vat and its photograph is given below.

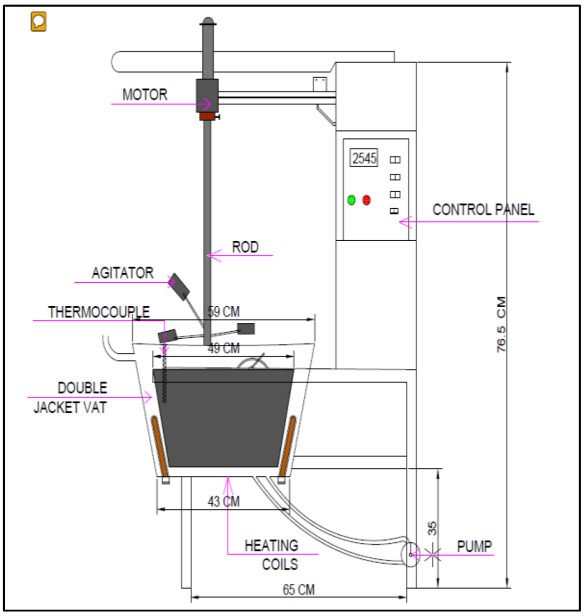

Fig 1: Line diagram of modified double jacketted vat

The double jacketed vat is mounted on a MS frame with dimension of 72cm and 76.5 mm.

Thermal efficiency
Thermal efficiency is an important parameter for thermal characterization of processing equipment. During the desiccation of milk only a part of thermo fluid is taken up by milk. A significant portion of heat is lost on account of several factors. E.g. heat loss due to outside air, heat loss from equipment etc. thermal efficiency is defined as ratio of heat taken by milk to heat given by thermo fluid.

$$\text{Thermal efficiency} = \frac{\text{Heat energy taken by milk}}{\text{Heat supplied by thermo fluid}} \times 100 = \frac{M_m C_{pm} (T_{mo} - T_{mi})}{M_{th} Cp_{th} (T_{th} - T_{th})} \times 100$$

M_m, M_{th}, C_{pm}, C_{pth}, are mass of milk and thermo fluid and specific heat of milk and thermo fluid. T_i and T_o are initial and final temperature recorded in thermocouple
Thus thermal efficiency of equipment provides the information on fraction of total heat utilized in heating of milk. It varies both equipment design & configuration, as well as type thermo fluid& capacity of milk in the vat.

Rate of water evaporation
Rate of water evaporation may be defined as amount of water evaporated in unit time from unit surface area

$$\text{Evaporation rate (kg/hr.m}^2\text{)} = \frac{amount\ of\ water\ evaporated}{total\ time\ taken} \times heat\ transfer\ area$$

Analytical Procedures
Analysis of milk for basundi making
Fat
Fat of milk used for basundi making was determined using Gerber method (IS1224:1977).

Solid not fat
SNF% of milk used was determined using gravimetric method described in (IS: 10083-1982). Following method was adopted for manufacture of Basundi.

Flow chart for manufacture of heat desiccated product (basundi)

Fresh milk
↓
Filtration
↓
Standardization
(Fat/SNF =0.6; fat= 5.1%; SNF=8.5%)
↓
Forewarming of milk
(90°C/10min)
↓
Concentration
(2.0 × milk solids)
↓ ➔sugar (6% on the milk basis)
Concentration continued
(2.5 × milk solids)
↓
Cooling

Flow chart of Basundi

Good quality milk was first standardized to adjust the fat SNF (5.1% and 8.5% SNF). Basundi was prepared in modified vat with 30kg milk. It was made by fore warming the milk at 90°C for 10 minutes. Then it was continuously desiccated up to its two fold concentration. Total solids were check out with refractometer during the preparation. Sugar was added after two fold concentration @6% on the milk basis. Then milk was allowed to desiccate to its 2.5 concentration. The prepared sample was allowed to cool.

Basundi prepared in karahi on LPG (control sample)

Four liters of milk were taken in SS karahi (open pan. Milk was first allowed to fore warmed at 90 for 10 minutes. Milk was desiccate at low temperature so that thin layer of flakes is formed at the top of milk. When the milk volume was reduced to 2 kg than sugar was added @ 6% on the milk basis. Then the milk was evaporated to its 2.5 fold concentration.

Analysis of product

Total solids

Total solids content of basundi was determined by the method recommended by BIS for the milk (IS: SP_18, 1981).

Acidity Titrable acidity was determined using the method described in IS: 1979(part-1)-1960.

Acidity (%L.A) = 9AN/W

Where,

A= vol. of NaOH used in titration (ml)

N= Normality of NaOH (0.1N)

W= wt. of basundi sample taken (gm)

Sensory evaluation of basundi prepared in modified vat and on LPG

The basundi samples were subjected for sensory evaluation by a panel of 5-7 judges. A 10 point hedonic scale was used for sensory attributes like flavor, body and texture, color and appearance overall acceptability.

Color analysis of basundi

Colour intensity of basundi sample was analysed in terms of reflectance measured by using reflectance meter under white mode. Reflectance meter was calibrated against 0 and 50 reflectance. Basundi sample was filled into a petriplate such that no air bubble was present in the sample when petriplate was covered with the lid. Then petriplate was wiped neatly and kept inverted below the bulb of reflectance meter. 4-5 readings of reflectance meter were recorded. Data was received through the software in terms of values for L* (lightness), 0 (black) to 100 (white); a* (redness), +60 (red) to -60 (green) and b* (yellowness), +60 (yellow) to - 60 (blue).

Results and Discussion

Preliminary study of properties of thermo fluids

For desiccation of milk products, it was important to study properties of thermo fluid for their selection. To start with, two thermo fluids were selected for the study i.e. paraffin and silicon oil. This selection was based on the properties of oil e.g. specific heat, viscosity, price and availability. Value of specific heat was reviewed from literature. Specific heat value of paraffin oil was 2.13 KJ/kg K and that of silicon oil was 1.09KJ/kg K and value of viscosity was 1000 Pa.s and 100 Pa.s for paraffin and silicon oil at 20ºC.

Specific heat is the amount of heat required to raise the temperature of unit mass of fluid by unit degree. Specific heat value indicated that paraffin oil would require more heat than silicon oil to raise its temperature. In other words, if same heat is supplied to both the thermo fluids than silicon oil will have higher rate of rise of temperature. Higher viscosity of paraffin oil indicated that it will take more time to let the temperature rise (Table 1).

Other properties like smoke point boiling point and increase in volume of oil heating were also studied.

Table 1: Properties of paraffin and silicon oil as reviwed from literature

Properties	Boiling point (°C)	Increase in volume (ml)	Smoke point (°C)	Viscosity (Pa.s)	Specific point (KJ/kg K)
Paraffin Oil	230	80	220	1000	2.13
Silicon Oil	245	110	170	100	1.09

From the analysis of properties of both thermo fluids, it was observed that thermo fluid having higher boiling point, higher smoke point, higher increase in volume on heating, should be selected.

Paraffin oil was found to have boiling point of 230°C and silicon oil had boiling point of 245°C but specific heat of paraffin oil was 2.13KJ/kg k which was higher than silicon oil having specific heat of 1.09KJ/kg K. Specific heat is the amount of heat required to raise the temperature of unit mass of fluid by unit degree. Specific heat value indicated that paraffin oil would require more heat than silicon oil to raise its temperature. In other words, if same heat is supplied to both the thermo fluids than silicon oil will have higher rate of rise of temperature.

Keeping all the desirable properties, paraffin oil was found to be more suitable as heat transfer medium.

Selection of medium of heating

For manufacture of heat desiccated product more amount of heat is to be transferred from thermo fluid to product. Trials were conducted on medium of heat by heating selected thermo fluid on LPG and on electric coil. When paraffin oil was heated on gas the maximum temperature reached was 150ºC in 10 minutes and rate of rise of temperature was 15ºC /minute. When heating was switch off then rate of cooling was 1.4ºC /minute. When heated on electric coil the rate of rise in temperature was 15ºC /minute but maximum temperature was 230ºC. Cooling rate was found to be 4.11ºC /minute as shown in Fig 2.

In case of silicon oil, on LPG heating maximum temperature reached was 160ºC and rate of rise of temperature was 18ºC, cooling rate was calculated as 1.22ºC as shown in Fig 3. On coil heating of silicon oil it was found that maximum temperature reached was 176ºC and rate of rise of temperature was 22ºC/ min, cooling rate was found to be 1.9ºC as shown in table 1 and figure 2 below.

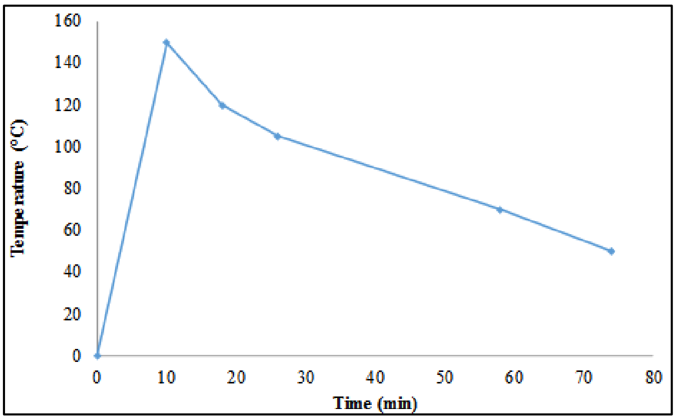

Fig 2: Time Temperature behaviour of paraffin oil on LPG heating

It was observed from the graph that maximum temperature obtained by paraffin oil was 150ºC and time taken to reach temperature is 10 minutes. The rate at which temperature rise was observed to be 15ºC/min.

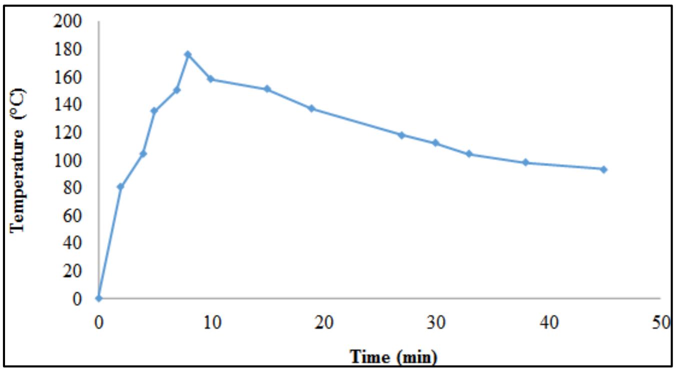

Fig 3: Time Temperature behaviour of silicon oil on LPG heating

Silicon oil on heating observed to reach maximum of 176ºC and time taken was 12 minute. Though the boiling point of silicon oil was 230ºC but heating was stopped due to smoke point of 176ºC (Fig. 3).

Temperature profile of thermo fluid when heated on coil

Paraffin and silicon oil of capacity one litre were taken & rise in temperature was observed.

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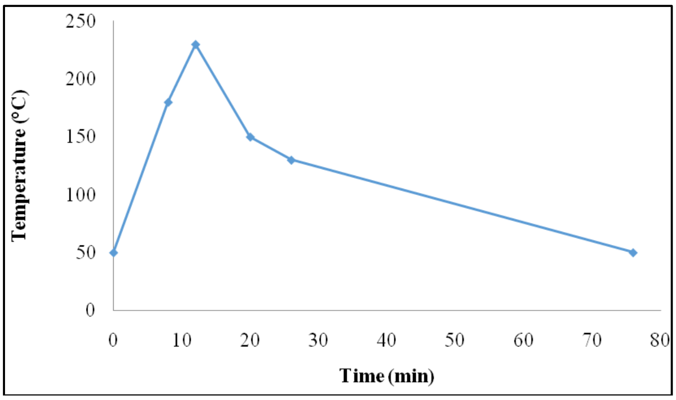

Fig 4: Time temperature behavior of Paraffin oil heating on electric coil

Paraffin oil reached maximum of 230ºC on coil heating in time 12 minutes. Cooling rate was found to be 4.11ºC/minute (Fig 4).

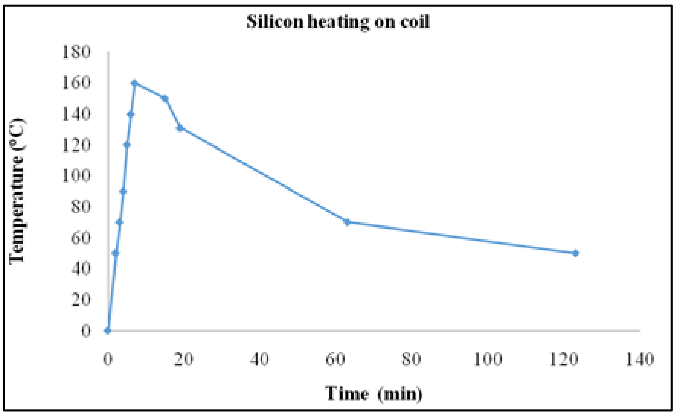

Fig 5: Time temperature behavior of Silicon oil heating on electric coil

The heating rate was observed to be 230°C in12min. Silicon oil when heated observed maximum of 176ºC in 7 mins but started smoking profusely so further heating was stopped. Increase in volume was also checked on heating (Fig 4 and Fig 5).

Table 3: Comparative time temperature behavior of paraffin and silicon oil

	Paraffin oil		Silicon oil	
	Gas heating	**Coil heating**	**Gas heating**	**Coil heating**
Maximum temperature	150ºC	230 ºC	160ºC	176ºC
Rate of rise/min	15ºC	15ºC	18ºC	22ºC
Rate of cooling/min	1.4ºC	4.1 ºC	1.22ºC	1.9ºC

From table 3, it can be concluded that higher temperature was reached in coil heating than gas heating. Also the rate of rise of temperature was higher in coil heating stating the fact that electric heating is more efficient than LPG heating. Same conclusion have been found by researcher Ketan, 2014 and Dingle, 2009 during their study using conical vat on LPG used for milk product manufacture.

From the preliminary trials it was concluded that based on literature review paraffin oil was more appropriate for heating purpose due to its high boiling point and for heating purpose, electrical coil heating was found to be more efficient than gas heating. Based on the results of the preliminary trials, it was concluded to proceed with paraffin oil as heating medium in double jacketed vat. To decide upon the capacity of vat and other processing parameters, trials were conducted for different volume of thermo fluid (paraffin oil) and water first and then milk which is given below.

Trials of paraffin oil in double jacketed vat

To study time temperature distribution of paraffin oil in the modified double jacketed cat20 liters of paraffin oil was taken in cavity and same volume (20 litres) of water was taken in vat. Heating started simultaneously for the paraffin oil as well as water in the vat. Temperature of paraffin thermo\s fluid increased from 30°C to 215°C in 55 minutes. The rate of rise of temperature was noted as 2.8°C/min. The temperature of water was found to rise to 100°C in 50 minutes. The difference in temperature of paraffin thermo fluid and water was less first and then increased as the time of boiling increased.

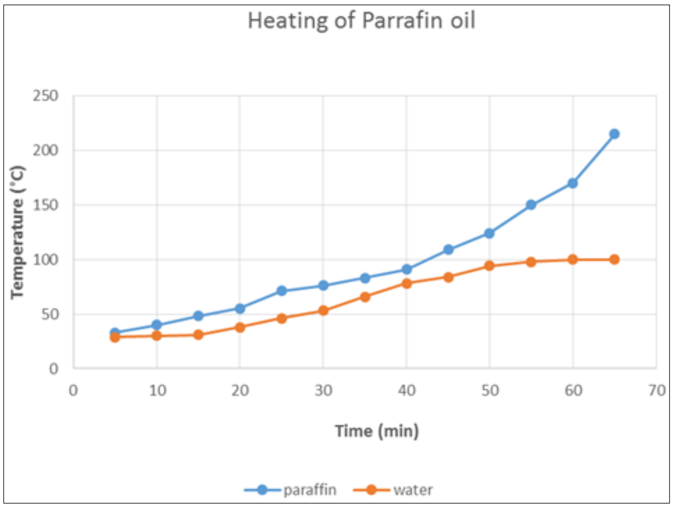

Fig 6: Temperature rise in paraffin oil and water in modified vat

Effect of 10 kg capacity on temperature profile of thermo fluid in modified vat

After development of modified vat it was important to determine the capacity of the bin at which it can have maximum thermal efficiency. Different volume of milk (10, 20, 30litres) was taken in vat and heated with paraffin oil and time temperature distribution was observed& thermal efficiency was calculated. The volume of thermo fluid was taken constant at 20 liters at which wet coil heaters were dipped in thermo fluid all the time

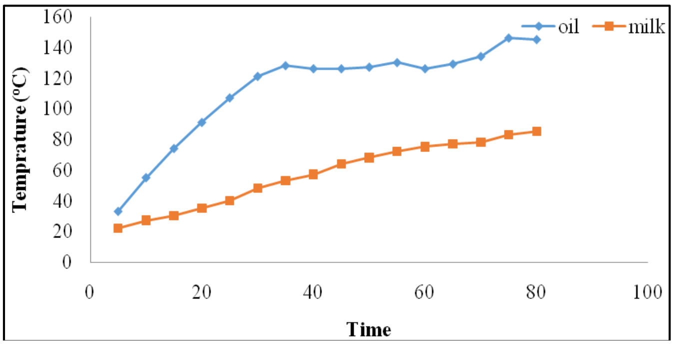

Fig 7 Temperature rise in milk and paraffin oil in modified vat (capacity 10 litres of milk)

As shown in fig 7, when 10 liters of milk was heated with paraffin oil and temperature of oil increase from 35ºC to 170ºC and temp of milk increased from 22ºC to 90ºC. The temperature of milk increased to 85ºC in 100 minutes the temperature of milk did not increase beyond 85ºC with increase in temperature of oil.

The thermal efficiency was calculated as 67.7% low as heat given by the thermo fluid got wasted and did not lead to rise in temperature of milk. The rate of evaporation was calculated to be 16.79kg/hr.m^2

Effect of 20 kg capacity on thermal efficiency

As shown in Fig. 8, temperature of paraffin fluid increased from 35°C to 155°C.The rate of rise of temperature of paraffin oil was 1.36°C/min and milk reached a maximum of 98°C and visually milk was boiling. When temperature of paraffin oil was increased further no increase in temperature of milk was found. As the heating continued and desiccation of milk took place, volume of milk reduced. As the volume of milk reduced to 14 liters the heat of thermo fluid got loss as the heat transfer area reduced. The rate of evaporation at 20 kg of milk handling capacity was 17.71kg/hr-m$_2$. The thermal efficiency was calculated to be 68.7%.

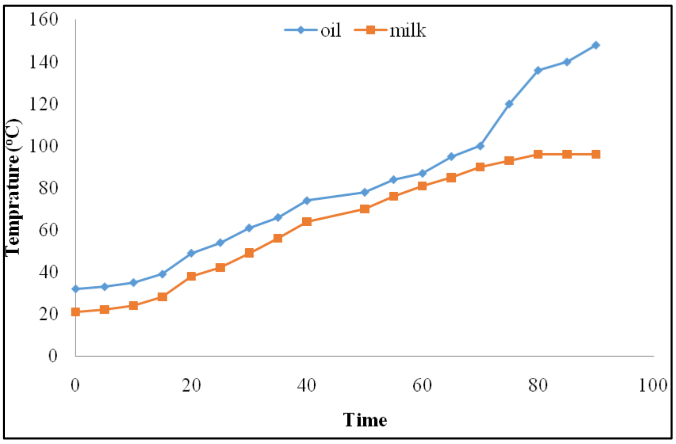

Fig 8: Temperature rise in milk and paraffin oil in modified vat (capacity 20 litres of milk)

Effect of 30 kg capacity on thermal efficiency

As shown in Fig. 9, when 30 liters of milk was heated with paraffin oil temperature of paraffin fluid increased from 31ºC to 127ºC and temperature of milk increased from 22ºC to 100ºC. The rate of rise of paraffin fluid was 0.83ºC/min and that of milk was 0.67ºC/min. The temperature of paraffin was set at 130ºC to reach the milk at its boiling point. As heating continued desiccation of milk took place and volume of milk reduced to 22 liters. The thermal efficiency at 30 kg milk handling capacity was 71.2% and rate of evaporation was calculated to be 19.8kg/hr.m^2.

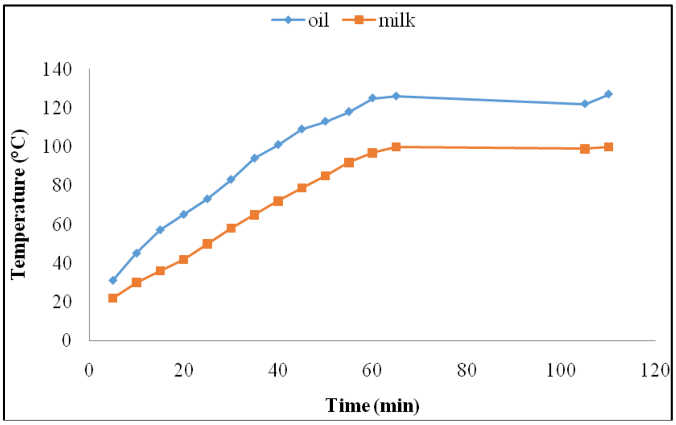

Fig 9: Temperature rise in milk and paraffin oil in modified vat (capacity 30 litres of milk)

Manufacture of heat desiccated product – basundi in double jacketed vat

The basic manufacturing steps followed in the preparation of basundi are similar to the traditional method. The flow diagram of the method followed of basundi in modified double jacketed vat is given in The forming of flakes is decisive characteristics for the quality of basundi. The graph shown in fig. 10 shows temperature profile analysis of basundi till boiling.

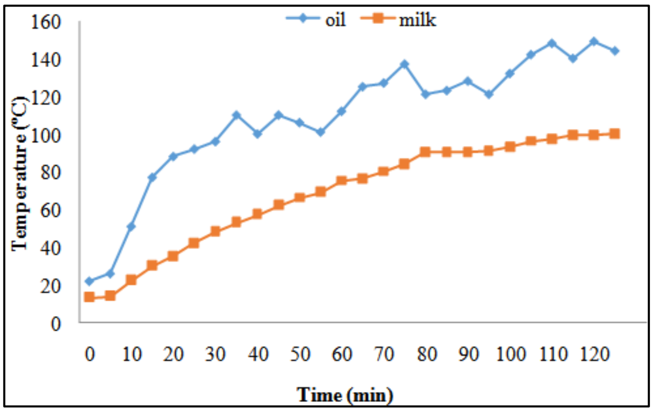

Fig 10: Temperature profile during Basundi manufacture in modified vat (capacity 30 litres of milk)

The temperature of oil was set at 140ºC and milk attained a temperature of 90 ºC which was maintained for 10 minutes for for-warming of milk. After 10 minutes the set temperature of paraffin oil was raised to 150ºC so that milk attained a boiling temperature. The yield obtained after basundi was made was 13kg. Total solid content of basundi manufactures in MDJV was 42-44%. Total time require for basundi making was 6 hours 10 minutes. The basundi manufacture in vat was compared with control sample manufactured on LPG.

Sensory evaluation of basundi prepared in modified vat and on LPG

The basundi prepared in modified vat was compared with control sample prepared on LPG. 30 kg of milk was taken in modified vat to prepare basundi. Basundi prepared in modified vat had more brown color as compared to control sample. Basundi prepared in modified vat had scored 7.3 in overall acceptability.

Table 4: Sensory evaluation of basundi

	Sample A(modified vat)	Sample B(control)
Flavor	7.6	7.7
Body and texture	7.4	8.0
Color and appearance	7.3	7.7
Overall acceptability	7.3	7.7

Colour analysis of basundi

The 'l' value varies with in the range of 0-100. Higher L value signifies the whiteness/lightness whereas lower value denotes dark colour product. On colour analysis it was found that basundi prepared in modified double jacketed vat had lower 'l' value i.e. 71.47 than basundi prepared on LPG heating i.e. 81.16.

A value varies with in the range of -60 to + 60 which signifies green and red color. Average value of a Basundi prepared in modified vat had higher value of 'a' and 'b' i.e. 8.89 and 26.225 respectively. The 'a' and 'b' values for basundi prepared on LPG are 4.89 and 22.20 respectively.

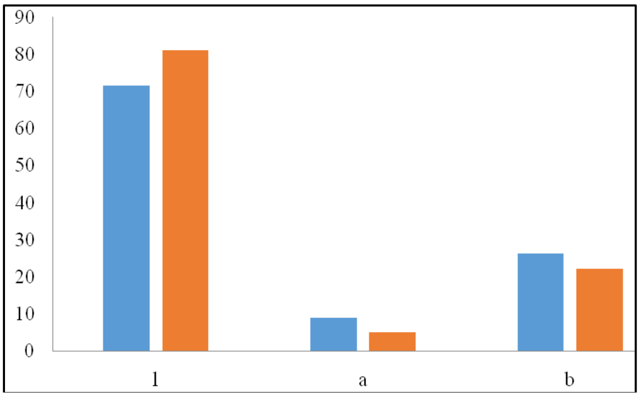

Fig 11: Colour analysis of basundi in terms of l, a and b values

Conclusion

In present study modified double jacketed vat was developed for mechanization of heat desiccated milk product e.g. basundi. The study includes the MDJV different capacity of milk in terms of colour and sensory evaluation of the product. The performance of the modified double jacketed vat was evaluated in terms of heating efficiency, rate of rise of temperature, sensory score and colour analysis of basundi prepared in it. Boiling point of paraffin thermo fluid was found to be more than silicon thermo fluid. Rate of rise of temperature was higher in coil heating than LPG heating. So, coil heating was employed in modified vat to heat selected thermo fluid. Existing vat was modified by increasing the thickness of cavity, which contained thermos fluid. Thermal efficiency was calculated to be maximum when paraffin oil was heated with 30 kg of milk handling capacity in vat. Rate of water evaporation increased with increase in capacity of milk in vat, as evaporation is surface phenomena so with increase in capacity more area was available for evaporation.

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