RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 13 | Issue 1 | April, 2020 | 113-120
ISSN–0974–2662 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/13.1/113-120**

# Performance evaluation of mechanized manufacture of bottle gourd *Halwa*

**C.S. Baladhiya, J.S. Doshi and V.B. Bhalodiya**

**Received :** 05.01.2020; **Revised :** 07.03.2020; **Accepted :** 20.03.2020

See end of the Paper for authors' affiliation

Correspondence to :

**C.S. Baladhiya**
Department of Agricultural Engineering, B.A. College of Agriculture, Anand Agricultural University,
**Anand (Gujarat) India**
Email: csbaladhiya@gmail.com

■ **ABSTRACT :** India has world's largest production of milk and 50-55 per cent of its production being used for the manufacture of different Traditional Indian Dairy Products (TIDP). The manufacture of traditional dairy products on large scale requires mechanization and optimization of operating conditions in order to get uniform acceptable quality. Scraped Surface Heat Exchanger (SSHE) of appropriate design is found suitable for production of highly viscous dairy products. Bottle gourd *Halwa* is one of the Traditional Indian Dairy Products (TIDP) prepared from grated bottle gourd cooked with *Ghee,* sugar, *Khoa,* and flavoured by spices like cardamom. The various unit operations involved in preparation of bottle gourd *Halwa* are shredding, cooking and desiccation with sugar and *Khoa*. The study was taken to evaluate heat transfer performance of the SSHE during manufacture of bottle gourd *Halwa* under variable operating conditions.The horizontal SSHE was used for the manufacturing of *Halwa* using the recipe standardized by Response Surface Methodology. The performance of the SSHE was evaluated at different scraper speeds and operating steam pressures. The rate of evaporation ranged between 12.379 and 19.947 kg water/h during manufacturing of *Halwa* in SSHE at different operating conditions. It was observed that overall heat transfer co-efficients (U-values) increased with the increase in scraper speed and steam pressure in range of 406 - 600 $W/m^2K$. The values of steam consumption and electrical power consumption under different operating conditions during manufacture of bottle gourd *Halwa* ranged from 18.56 to 36.76 kg/h and 0.398 to 0.410 kWh, respectively. The values of specific steam consumption ranged from 1.659 to 1.697 kg steam/kg water evaporated. The total heat losses during manufacture of *Halwa* in the SSHE ranged from 20.84 to 23.83 per cent of the heat input at different steam pressures and scraper speeds.

■ **KEY WORDS :** Bottle gourd *Halwa*, Scraped surface heat exchanger, Energy analysis, Sensible heat

■ **HOW TO CITE THIS PAPER :** Baladhiya, C.S., Doshi, J.S. and Bhalodiya, V. B. (2020). Performance evaluation of mechanized manufacture of bottle gourd *Halwa*. *Internat. J. Agric. Engg.*, **13**(1) : 113-120, **DOI: 10.15740/HAS/IJAE/13.1/113-120.** 

Indigenous dairy products have played an important role in socio-economic life of Indian people.India's market potential and current growth rate of traditional dairy products is unparalleled and all set to boom further under the technology of mass production.The operation flood programme, one of the world's largest and most successful integrated dairy development programme initiated in 1970 had led India to emerge as the world's largest producer of milk. The milk production of India has reached to 176.3 million tonnes per annum in the year 2017-18, accounting for more than 19 per cent of the world's total production. About 50-55 per cent of the total milk produced in India is converted into traditional milk products. The manufacture of traditional milk products is mainly confined to the cottage scale in the non-organized sector (Dodeja, 2014; Patel and Bhadania, 2015). The traditional milk products in India have great significance as they account for over 90 per cent of all dairy products consumed in the country (Aneja *et al.*, 2002). The dairy plants have shown interest for large scale manufacture of Traditional Indian Dairy Products (TIDP) by adopting mechanized systems for their production. This is mainly due to increase in demand and better profit margin in sale of TIDP. Moreover, increased availability of milk and decrease in the demand of *Ghee* and butter are the probable reasons to venture in the business of Traditional Indian Dairy Products (Dhotre, 2006).

Traditional dairy products not only have established market in India but also have great export potential because of strong presence of Indian diaspora in many parts of world (Rao and Raju, 2003). The market for traditional Indian milk products is very large, fast growing and is likely to increase at an annual growth rate of about 20 per cent (Aggarwal, 2007). The manufacture of traditional dairy products helps the milk producers to fetch better price of milk and provides an opportunity for employment generation in rural and semi-rural areas. A variety of traditional milk products such as *Khoa* and *Khoa* based sweets, *Paneer, Shrikhand, Rabri, Kheer, Halwa, Basundi*, fermented products and many region specific traditional ethnic products are being manufactured in India. At present, 150 type of milk based sweetmeats are available in Indian market. *Halwa* of various types are very popular in Indian market as sweetmeats with very rich nutritional value. It is widely used in festivals, marriages, feasts, religious functions as well as in daily menus.

Bottle gourd *Halwa (Lauki ka halwa/Doodhi halwa)* is a mouth-watering sweet dish prepared from grated *Lauki* or bottle gourd cooked with sugar, *Khoa* and flavoured by spices like cardamom. The product quality and attributes vary considerably from *Halwais* to *Halwais* depending on the skill of the *halwais* as well as proportion of various ingredients used in the preparation of Bottle gourd *Halwa*.

The commercial production of any food product depends on the availability of appropriate manufacturing and processing technology. Many small and medium scale dairy entrepreneurs are interested to adopt mechanization in production of many TIDP including various types of *Halwas*. The various unit operations involved in preparation of bottle gourd *Halwa* are shredding, cooking and desiccation with sugar and *Khoa*. These operations can be mechanized by using scraped surface heat exchanger (SSHE) which efficiently carry out cooking and partial desiccation operations. It is necessary to develop and standardize a commercial method of manufacturing bottle gourd *Halwa*, which can be adopted at industrial level.

## ■ METHODOLOGY

### Raw materials used for the manufacture of bottle gourd *Halwa:*

The raw materials used for the preparation of bottle gourd *Halwa* are bottle gourd, *Khoa*, sugar, *Ghee*, food grade colour and cardamom. Bottle gourd (cv. ABG-1) fruits and white crystalline sugar of commercial grade free from impurities were purchased from the Main Vegetable Research Station, AAU, Anand and local market of Anand, respectively. *Khoa* and *Ghee* were procured from the Department of Dairy Processing Operations (Anubhav Dairy), Sheth M.C. College of Dairy Science, Anand Agricultural University, Anand.

### Scraped surface heat exchanger:

The horizontal type scraped surface heat exchanger (SSHE) designed by Jain (2010) was used for the manufacture of the *Halwa* and optimization of the operating parameters of the SSHE. This design has all features required to handle viscous product and has adequate area for the escape of vapour. The horizontal type SSHE is more efficient in heat transfer (Abichandani and Sarma, 1989) and process variables can be easily controlled.

The SSHE consists of jacketed product tube, spring loaded scraper assembly, vapour hood, drive arrangement for the scraper assembly and measuring and controlling instruments. These components of the SSHE have been mounted on stainless steel frame along with provision for supplying steam and removal of condensate from the jacket as shown in Plate 1.

**Plate 1 : Scraped surface heat exchanger**

### Product tube:

Steam is used as heating medium in the SSHE during manufacture of the products and which is supplied in the jacket of the product tube. The product tube has a bore (D) of 500 mm and length (L) of 600 mm. The product tube has a jacket which covers 550 mm length of SSHE leaving 25 mm length unjacketed on both side. The lower half of the product tube has a jacket while upper side less than half portion has holes for the removal of vapour during the process. The unjacketed area of the product tube on the top consists of 208 holes each of 18 mm diameter for the escape of the vapour from the product tube. The annular space between jacket and the product tube is 25 mm having total volume of 11.34 liters in which steam is supplied.

### Rotor-scraper assembly:

The scraper assembly of the SSHE consists of a solid stainless steel shaft of 25 mm diameter on which supports for holding blades were welded. The four scraper blades were fixed on these supports after placing S.S. springs so as to provide necessary contact pressure for effective scraping of the product. The spring loaded Teflon edged scraper blades were arranged in such a way that the whole surface was efficiently scraped during operation of the SSHE.

### Drives for scraper assembly:

An A. C. motor (1.5 kW, 3-phase) was used to drive the assembly through a worm gear box having speed reduction ratio of 15:1. The power is transmitted from gearbox to scraper assembly through V-belt. A Variable Frequency Drive (VFD) was used to regulate the speed of motor required to operate the scraper assembly at different speeds for experimental trials.

### Energy supply for SSHE:

The SSHE used for the manufacture of *Halwa* for experimental trials requires electrical energy for operation of three phase induction motor which drives scraper assembly. The steam generated in the Non-IBR boiler was supplied to the SSHE. The steam is supplied at required pressure by regulating the hand operated steam valve provided in the steam pipeline. The heat and mass balance equations were developed to carry out thermal analysis of the SSHE.

### Parameters for evaluation of SSHE:

The performance evaluation of the SSHE in terms of engineering parameters and the quality attributes of the product is very important for adoption of mechanization in the manufacture of bottle gourd *Halwa*. The operating variables greatly influence the quality of the final product.

The performance of the SSHE was evaluated at different scraper speeds ($S_1$=10 r.p.m., $S_2$=20 r.p.m., $S_3$=30 r.p.m.), operating steam pressures ($P_1$=1.0 kg/cm$^2$, $P_2$=1.5 kg/cm$^2$, $P_3$=2.0 kg/cm$^2$) keeping batch size of 10 kg shred in all the experimental trials during manufacture of bottle gourd *Halwa*.

### Manufacture of bottle gourd *Halwa* in SSHE:

The flow diagram of the method followed for the manufacture of bottle gourd *Halwa* in SSHE is presented in Fig. 1. Ghee at the rate optimized by the Design Expert 9.0.3.1 software was taken in the clean and dry SSHE. The scraper assembly was started and steam was admitted in the jacket of the SSHE. On heating the *Ghee*, shredded bottle gourd was added in the SSHE through feed hopper. When shredded bottle gourd was semi-cooked, a measured quantity of water was added in the machine as per requirement for cooking of the shred. When the bottle gourd shred was cooked properly, sugar was added in the SSHE. Then, the grated *Khoa* was added in the SSHE. The permitted colour was added at the later part of the process to impart little greenish appearance to the product. On achieving desired lump

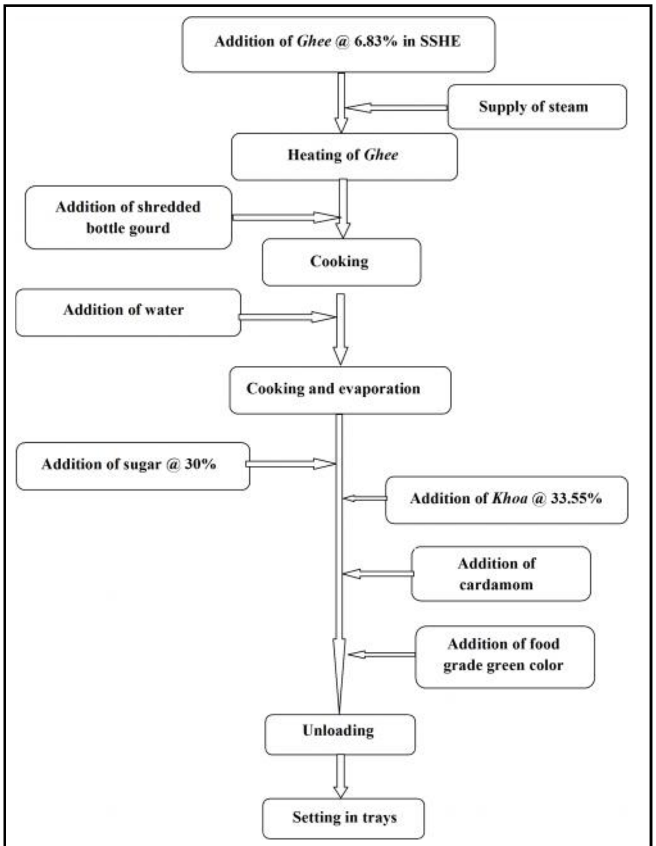


**Fig. A : Flow diagram for manufacture of bottle gourd *Halwa* in SSHE**

formation, the steam supply was discontinued and the product was removed from the SSHE and transferred to trays for cooling and setting.

## Steam consumption:

The steam consumption of the SSHE was estimated by measuring the quantity of condensate coming out from the steam trap of the jacket. In order to eliminate the effect of flash vapour leaving the steam trap, chilled water was taken in the container in which the end of hose pipe was dipped. The difference of initial weight of chilled water and the final weight of the water is taken as the amount of steam used in the trial.

## Electrical power consumption:

The electrical energy consumption (input voltage, current and power) of the SSHE was measured by power analyzer (MICO, 3-$\phi$ , 4-wire power analyzer, 440 volt) and energy meter installed in the electrical circuit.

## Heat transfer evaluation of SSHE:

Sensible heat transfer:

The sensible heat transfers in raw materials were calculated as under.

Sensible heat required for bottle gourd shred,

$$Q_{sb} = m_b \times C_b \times (t_2 - t_1) \quad \ldots\ldots(1)$$

where, $Q_{sb}$= Sensible heat of bottle gourd shred, kJ
$m_b$= Mass of the shredded bottle gourd, kg
$C_b$= Specific heat of bottle gourd shred, kJ/kg K
$t_1$= Initial temperature of bottle gourd shred, $^0$C
$t_2$ = Final temperature of evaporation, $^0$C

Sensible heat required for sugar,

$$Q_{SS} = M_s \times C_S \times (t_2 - t_1) \quad \ldots\ldots(2)$$

where, $Q_{ss}$= Sensible heat of sugar, kJ
$M_s$= Mass of the sugar, kg
$C_s$ = Specific heat of sugar, kJ/kg K
$t_1$= Initial temperature of sugar, $^0$C
$t_2$ = Final temperature of evaporation, $^0$C

Sensible heat required for *Khoa*,

$$Q_{Sk} = M_k \times C_k \times (t_2 - t_1) \quad \ldots\ldots(3)$$

where, $Q_{sk}$= Sensible heat of *Khoa*, kJ
$M_k$ = Mass of the *Khoa* kg
$C_k$= Specific heat of *Khoa*, kJ/kg K
$t_1$= Initial temperature of *Khoa*, $^0$C
$t_2$ = Final temperature of evaporation, $^0$C

Sensible heat required for *Ghee*,

$$Q_{Sg} = M_g \times C_g \times (t_2 - t_1) \quad \ldots\ldots(4)$$

where, $Q_{sg}$= Sensible heat of *Ghee*, kJ
$M_g$ = Mass of the *Ghee*, kg
$C_g$ = Specific heat of *Ghee*, kJ/kg K
$t_1$= Initial temperature of *Ghee*, $^0$C
$t_2$ = Final temperature of evaporation, $^0$C

Therefore, total sensible heat required,

$$Q_S = Q_{Sb} + Q_{SS} + Q_{Sk} + Q_{Sg} \quad \ldots\ldots(5)$$

## Latent heat transfer:

The latent heat transfer during the process was calculated using the following equation.

$$Q_l = E \times L \quad \ldots\ldots(6)$$

where,
$Q_l$= Latent heat, kJ
E = Total evaporation of water, kg/batch
L = Latent heat of evaporation, kJ/kg

As the evaporation takes place at atmospheric pressure, latent heat of evaporation (L) at atmospheric pressure was taken as 2257 kJ/kg.

**Determination of overall heat transfer co-efficient:**

The SSHE has a half jacketed product tube equipped with rotor-scraper assembly for continuous scraping of the product. The heat transferred from steam to the product was used for cooking and evaporation of water during manufacture of bottle gourd *Halwa.* Therefore, heat transfer Q, was determined by the heat uptake equation.

Now, using Fourier's heat flow equation,

$$Q_s + Q_1 = U \times A \times (T_s - T_p) \quad \text{........} \quad (7)$$

where,

U = Overall heat transfer co-efficient, $W/m^2K$

A = Effective heat transfer area of the SSHE, $m^2$

$T_s$ = Temperature of steam corresponding to steam pressure, $^0C$

$T_p$ = Temperature of the product, $^0C$

The heat transfer area A is based on the logarithmic mean radius $r_m$ of the cylindrical wall of the SSHE.

**Energy analysis of the SSHE:**

Steam is supplied in the jacket through a steam valve and the condensate leaving the steam trap of the SSHE was measured.

The heat energy input with steam is equal to the amount of steam supplied multiplied by the enthalpy of the steam. The energy leaving the SSHE consists of heat energy of condensate, energy of evaporated water and the energy of the product leaving the SSHE. From the above discussion the heat balance equation for the SSHE is as under.

Rate of heat energy input = Rate of heat energy leaving the SSHE + Losses

**Heat energy with the feed materials** + **Heat energy of steam** = **Heat energy of condensate** +

**Heat energy of evaporated water** + **Energy going with the product** + **Energy losses**

$$(m \times C_P \times T_i) + S_1 (h_s) + X \times h_1) = (S_1 \times C_{pc} \times T_{s1}) + (E + H_v) + (m_p \times C_{PP} \times t_1) + E_1 \quad \text{........}(8)$$

where,

m = mass of each material, kg

$C_p$ = specific heat of material, kJ/kg K

Ti = Initial temperature of each feed material, $^0C$

$h_s$ = Sensible heat of steam, kJ/kg K

X = Dryness fraction of steam

$h_l$ = Latent heat of steam, kJ/kg

$C_{pc}$ = Specific heat of condensate, kJ/kg K

$S_1$ = Quantity of steam used, kg/h

$T_{s1}$ = Saturation temperature of condensate, $^0C$

E = Evaporation rate of water, kg/h

$E_l$ = Energy loss, kJ/h

$H_v$ = Enthalpy of evaporated water, kJ/kg

$m_p$ = Mass of the product leaving the SSHE, kg

$C_{pp}$ = Specific heat of the product, kJ/kg k

$t_1$ = Temperature of the product leaving the SSHE, $^0C$

## ■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

**Manufacture of bottle gourd *Halwa* in the SSHE:**

The performance evaluation in terms of energy requirement of the SSHE and quality of the product under different conditions was also carried out for the process. The effective scraping of heat transfer surface of SSHE is the key factor to prepare *Halwa* in mechanized process. Therefore, the scraper of the SSHE was modified in order to get optimum scraping action during the manufacture of *Halwa.* The spring loaded scraper blades having Teflon edge maintains required optimum scraping pressure on the surface of SSHE.

The heat transfer evaluation of the SSHE includes determination of overall heat transfer co-efficient, energy analysis as well as thermal and electrical energy requirement during operating conditions of the SSHE.

The preparation of the *Halwa* mainly involves two stages, *viz*., steaming for cooking of bottle gourd shred and evaporation of water from the blend of bottle gourd shred and sugar to achieve required final consistency of the product. The experimental trials were conducted by varying steam pressure and scraper speed.

**Evaporation of water at different operating conditions:**

The Table 1 indicates the average values of rate of evaporation (kg water evaporated/h) in the SSHE at different steam pressures and scraper speeds during

**Table 1 : Rate of evaporation and U-values of SSHE during manufacture of *Halwa* at different steam pressure and scraper speed**

| Steam Pressure $kg/cm^2$ (kPa) | Scraper speed (rpm) | Rate of evaporation (kg water/h) | U-value ($W/m^2K$) |
|---|---|---|---|
| 1.0 | 10 | 11.190 | 405.70 |
| (98.1) | 20 | 12.433 | 452.28 |
| | 30 | 13.828 | 501.63 |
| 1.5 | 10 | 13.928 | 430.85 |
| (147.15) | 20 | 14.920 | 461.77 |
| | 30 | 16.785 | 519.54 |
| 2.0 | 10 | 17.615 | 492.47 |
| (196.2) | 20 | 19.180 | 534.08 |
| | 30 | 21.658 | 599.52 |

Each value is an average of three replications

*Halwa* making process. The rate of evaporation ranged between 12.379 to 19.947kg water evaporated/h during manufacturing of *Halwa* at different operating conditions. It can be observed that, the rate of evaporation increased with the increase in scraper speed and steam pressure during manufacture of *Halwa*

**U-values at different operating conditions of SSHE:**

The overall heat transfer co-efficients (U-values) during manufacture of bottle gourd *Halwa* in SSHE were determined as mentioned in materials and method. The average U-values obtained from the data collected under various operating conditions during manufacturing of *Halwa* in the SSHE are shown asabove. The U-values obtained during manufacturing of *Halwa*in SSHE ranged from 405.70 to 599.52W/m$^2$K at various combinations of operating parameters *viz*., steam pressure and scraper speed. It was observed from the graph that U-value increased with increase in steam pressure and scraper speed during *Halwa* making process. Many research workers have reported positive significant effect of steam pressure and scraper speed on U-values during manufacture and processing of similar product in SSHE (Bhadania, 1998; Patel, 2013; Dhotre, 2006; Jain, 2010; Dodeja and Deep, 2012). However, in the process of mechanized manufacture of *Halwa*, it is essential to control the rate of evaporation to get adequate time for cooking of the product. U-values depend on the rate of evaporation and in the present design of SSHE and operating conditions, U-values of about 500-525 W/m$^2$K was achieved to get desirable quality of the *Halwa*. The regression equations obtained co-relating U-values and scraper speed were $y = 4.7965x + 357.27 (R^2 = 0.9997)$, $y = 4.4345x + 382.03 (R^2 = 0.9704)$, and $y = 5.3525x + 434.97 (R^2 = 0.9838)$ at 1.0, 1.5 and 2.0 kg/cm$^2$ steam pressure. These equations are useful to determine U-values at other operating speeds of the scraper for design and optimization of SSHE.

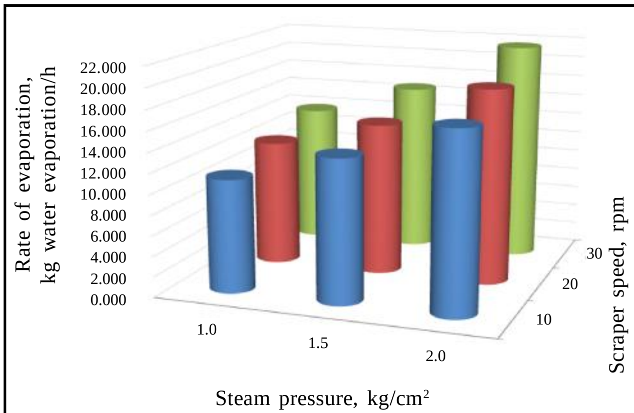


**Fig. 1 : Effect of steam pressure on rate of evaporation during manufacture of *Halwa***

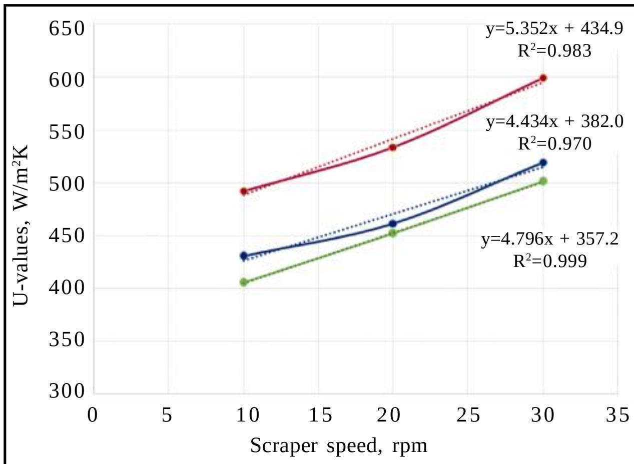


**Fig. 2 : Effect of steam pressure on U-value during manufacture of *Halwa***

**Table 2: Steam and electrical power consumption of the SSHE during manufacture of bottle gourd *Halwa***

| Steam pressure kg/cm$^2$ (kPa) | Scraper speed rpm | Rate of evaporation kg water/h | Steam consumption kg/h | Specific steam consumption (kg steam/ kg water evaporated) | Electrical power consumption Wh |
|---|---|---|---|---|---|
| 1. 0 | 10 | 11.190 | 18.60 | 1.662 | 398.4 |
| (98.1) | 20 | 12.433 | 20.79 | 1.672 | 400.3 |
| | 30 | 13.785 | 23.20 | 1.683 | 405.8 |
| 1.5 | 10 | 13.928 | 23.10 | 1.659 | 395.2 |
| (147.15) | 20 | 14.920 | 24.73 | 1.658 | 399.5 |
| | 30 | 16.785 | 27.90 | 1.662 | 408.3 |
| 2.0 | 10 | 17.615 | 29.40 | 1.669 | 396.5 |
| (196.2) | 20 | 19.050 | 32.12 | 1.686 | 398.6 |
| | 30 | 21.350 | 36.10 | 1.691 | 410.2 |

**Table 3 : Heat energy input, output and heat losses during manufacture of bottle gourd *Halwa***

| Steam pressure kg/cm$^2$ (kPa) | Scraper speed rpm | Heat energy of feed kJ/h | Heat energy of steam kJ/h | Heat energy of condensate kJ/h | Heat energy of evaporated water kJ/h | Heat energy of product leaving kJ/h | Energy losses kJ/h | Energy losses (%) |
|---|---|---|---|---|---|---|---|---|
| 1. 0 | 10 | 1474.43 | 45791.76 | 5995.19 | 29944.44 | 1579.90 | 9746.65 | 21.28 |
| (98.1) | 20 | 1638.26 | 51183.37 | 6701.07 | 33270.71 | 1764.10 | 11084.11 | 21.66 |
| | 30 | 1882.25 | 57116.60 | 7477.87 | 36888.66 | 2022.86 | 12609.46 | 22.08 |
| 1.5 | 10 | 1769.32 | 57149.35 | 7735.73 | 37271.33 | 1960.05 | 11951.57 | 20.91 |
| (147.15) | 20 | 1965.91 | 61181.97 | 8281.58 | 39925.92 | 2188.61 | 12751.76 | 20.84 |
| | 30 | 2211.65 | 69024.54 | 9343.15 | 44916.66 | 2464.61 | 14511.76 | 21.02 |
| 2.0 | 10 | 2268.35 | 73046.79 | 10091.61 | 47137.74 | 2525.32 | 15560.48 | 21.30 |
| (196.2) | 20 | 2527.59 | 79804.86 | 11025.25 | 50977.80 | 2822.25 | 17507.16 | 21.94 |
| | 30 | 2853.74 | 89941.97 | 12425.72 | 55660.80 | 3272.48 | 21436.70 | 23.83 |

## Evaluation of energy requirement of SSHE during *Halwa* making:

*Thermal energy requirement:*

The values of steam consumption under different operating conditions were in range of 18.56 to 36.76 kg/h (Table 2). The steam consumption increased with the increase in steam pressure and scraper speed during manufacturing *Halwa* in the SSHE. The values of specific steam consumption under different operating conditions ranged between 1.659 and 1.697 kg steam/kg water evaporated.

*Electrical energy requirement:*

These values ranged from 398.4 to 410.2 Wh under different operating conditions. The data in Table 2 indicates the rise in the electrical power consumption with the increase in scraper speed. The average power consumption to drive the machine during *Halwa* making was 0.400 kWh. The electrical power consumption of the SSHE is relatively very small as compared to thermal energy required. Similar observation has been reported by Bhadania (1998); Dhotre (2006) and Dodeja and Deep (2012) during manufacture of *Khoa* and thermal processing of dairy products.

The energy components of heat input, heat output and heat losses are presented in Table 3. These components of energies are expressed per hour and showed increasing trend with increase in steam pressure and scraper speed. The total heat losses during manufacture of *Halwa* in the SSHE ranged from 20.8 to 23.8 per cent of the heat input as steam, at different steam pressures and scraper speeds.

## Conclusion :

The following conclusions have been derived from the study.

The design of the SSHE can be successfully used to manufacture bottle gourd *Halwa*. The rate of evaporation ranged between 12.379 and 19.947kg water/h during manufacturing of *Halwa* at different operating conditions. The rate of evaporation increased with the increase in scraper speed and steam pressure.

The U-values of the SSHE increased with increase in steam pressure and scraper speed during *Halwa* making process. The range of U-values ranged between 500-525 W/m$^2$K under various operating condition of the SSHE. The statistical analysis of the data revealed that the main effects of steam pressure was found to have significant effect on the values of overall heat transfer co-efficients during manufacturing of *Halwa* at 5% level of significance.

The values of steam consumption and electrical power consumption under different operating conditions during manufacture of bottle gourd *Halwa* ranged from 18.56 to 36.76 kg/h and 398.4 to 410.2 Wh, respectively. The values of specific steam consumption under different operating conditions ranged from 1.659 to 1.697 kg steam/kg water evaporated.

The energy components of heat input, heat output and heat losses showed increasing trend with increase in steam pressure and scraper speed. The total heat losses during manufacture of *Halwa* in the SSHE ranged from 20.84 to 23.83 per cent of the heat input by the steam, at different steam pressures and scraper speeds.

Authors' affiliations:

**J.S. Doshi,** Regional Research Station (A.A.U.), **Anand (Gujarat) India**

**V.B. Bhalodiya,** Department of Agricultural Engineering, Anand Agricultural University, **Anand (Gujarat) India**

## REFERENCES

**Abichandani, H. and Sarma, S.C. (1989).** Power requirement during concentration of milk and cream in horizontal thin film scrapped surface heat exchanger. *Indian J. Dairy Sci.,* **42** (2) : 155-158.

**Aggarwal, S.S. (2007).** Indian traditional milk product sector, In: Dairy India, 6th Edition, Dairy India Year Book, New Delhi, pp. 405-407

**Aneja, R.P., Mathur, B.N., Chandan, R.C. and Banerjee, A.K. (2002).** Technology of Indian Milk Product. Dairy India Year Book, Dairy India Publication, New Delhi pp. 133-142

**Bhadania, A.G. (1998).** Development and Performance Evaluation of Continuous *Khoa* making Machine. Ph. D. Thesis, Gujarat Agricultural University, SK. Nagar, Gujarat.

**Dhotre, A.V. (2006).** Development and performance evaluation of scraped surface heat exchanger for continuous thermization of shrikhand. M. Tech. Thesis, MC College of Dairy Science, AAU, Anand.

**Dodeja, A.K. and Deep A. (2012).** Mechanized manufacture of *danedar* khoa using three stage SSHE. *Indian J. Dairy Sci.,* **65**(4): 274-284.

**Dodeja, A.K. (2014).** Application of SSHE for mechanized production of Indian Dairy Products. Compendium of ICAR sponsored summer school on "Engineering interventions in processing and value addition of milk and milk products" organized by National Dairy Research Institutes, ICAR, Karnal, pp. 6-10.

**Jain, S. (2010).** Development of Multipurpose Scraped Surface Heat Exchanger for Mechanization of Selected Indigenous Dairy Products. M. Tech. Thesis, Anand Agricultural University, Anand.

**Patel, S. (2013).** Mechanized manufacturing of Traditional Indian Dairy Product. Compendium of national seminar on "Mechanised production of Indian dairy products" organized by Indian Dairy Engineering Association (IDEA) at Andheri (E), Mumbai, pp. 44-51.

**Patel, S.M. and Bhadania, A.G. (2015).** Mechanized production of Traditional Indian Dairy Product: Present status, Opportunities and Challenges, Compendium of national seminar on "Indian Dairy Industry – Opportunities and Challenges" organized by SMC College of Dairy Science, Anand, pp. 214-222.

**Rao, K.H. and Raju, P.N. (2003).** Prospects and challenges for Indian Dairy Industry to export dairy products. *Indian J. Dairy & Bio Sci.*, **14**(2): 72-78.

13th Year
★★★★★ of Excellence ★★★★★