Mechanized Manufacture of Danedar Khoa using Three Stage SSHE

A.K. Dodeja and Ankit Deep
National Dairy Research Institute, Karnal-132001 (Haryana)

The present investigation is undertaken to explore the feasibility of three stage SSHE for manufacture of danedar khoa. Trails were conducted to optimise the process parameters such as initial acidity of milk, mass flow rate, steam pressure and scraper speed. Initial acidity of milk was varied from 0.16 to 0.19% LA. The mass flow rate was varied between 170 to 210 kg/h. Three levels of scraper speed were taken in first, four levels in second stage and three levels in third stage i.e. 200, 175, 150 rpm, 200, 175, 150, 125 and 25, 20, 15 rpm respectively. The quality of danedar khoa so produced was evaluated in terms of sensory evaluation and textural profile analysis. The best quality of danedar khoa was prepared by using standardized milk with 0.18% LA initial acidity and keeping scraper speed 175, 150, 15 rpm for first, second and third stage SSHE and flow rate 190 kg/h and steam pressure 4, 2 and 1.5 kg/cm².

Keywords: Scraped surface heat exchanger (SSHE), Danedar Khoa, heat transfer coefficient

INTRODUCTION

Khoa is partially dehydrated, heat desiccated milk product and it is widely used as a base material for preparation of numerous indigenous sweets. The increasing demand of khoa based indigenous sweets has created need for large scale industrial production, ensuring uniform product quality, product safety, energy conservation, etc. Development of an industrial scale khoa making plant has been a challenge to dairy scientists since several years. Many efforts have been made in mechanization of khoa making process to improve heat transfer and also to overcome the drawbacks of traditional methods as well as to commercialize the process for industrial requirements. Extensive studies were also carried out on the hydrodynamics and heat transfer of thin film scraped surface heat exchanger (TFSSHE) for processing of liquid, concentrated liquids, and particulate viscous foods. Studies were also undertaken on the applicability of thin film scraped surface heat exchanger (SSHE) for the mechanization of khoa.

According to PFA rules, revised in 2002, khoa is a product obtained from cow or buffalo milk or a combination thereof by rapid desiccation and having not less than 30% fat on dry matter basis of the finished product. According to Indian Standards (IS: 4883-1980), khoa shall be heat coagulated milk-product obtained by partial dehydration of milk of buffalo, cow, sheep, and goat or their admixture. Milk solids suitably processed may also be used. It shall not contain any ingredient foreign to milk except citric acid in danedar khoa added to develop desirable characteristic.

A large variation in quality of market surplus indicates three major varieties of khoa viz. pindi, dhap and danedar. Chemical composition, sensory characteristics and end uses of such varieties are found to be different. These varieties of khoa are received in Delhi market, which is the biggest khoa marketing centre in the country today. These types of khoa differ in quality and also in price. All of these varieties are in demand and are required for specific types of sweets as shown below (De, 1980).

Gross composition and specific sweets prepared from different khoa is given in Table-1.

The work on continuous khoa making machine gained momentum in recent years as a result of greater emphasis laid for the manufacture of indigenous milk products in the organized sector. For handling high viscosity products with or...
without particulates, and for the products that tends to foul the heat transfer surface, the thin film scraped surface heat exchanger (SSHE) is most suitable.

Khoa is the basic ingredient in most of milk based sweets. However, no systematic attempt has been made in the development of scientific methods for predicting equipment performance, suited to the formation of desirable texture of Indigenous dairy products. Since there is scanty knowledge of basic research data pertaining to the texture of the khoa, it has been difficult to make ameliorative effort to mechanize the process of khoa production with desirable texture. The three stage SSHE developed for the manufacture of khoa was attempted for the mechanized manufacture of danedar khoa

Hence the present dissertation work is envisaged to produce danedar khoa using thin film scraped surface heat exchanger.

MATERIALS AND METHODS

Selection of Raw material

Milk

Fresh buffalo milk and Skimmed milk were procured from Experimental Dairy NDRI, Karnal. Standardization was done to 6% Fat and 9% SNF. Acidity was increased up to 0.18% LA.

Caustic Solution

Caustic solution of 0.75% strength was prepared by using sodium hydroxide flakes LR grade for CIP of TFSSHE.

Water

Potable water available at Dairy Engineering Division was used for washing and cleaning.

Experimental Procedure

Preparation of khoa in Three Stage Scraped Surface Heat Exchanger

The operating features and performance of operation of three stage SSHE has been described elsewhere (Sharma, 2007). The photograph of experimental set-up is given in Plate-1 and flow diagram in Plate-2. Buffalo milk was poured into balance tank through sieve to filter any extraneous matter out. Then milk flow was varied between 170- 210 kg/hr with the help of electromagnetic flow meter by controlling the rpm of feed pump from the control panel. The scrapper blade assembly of all SSHEs were set their pre-decided rpm by control panel. The steam pressure in first and second stage was fixed at 4 kg/cm² and 2 kg/cm² (gauge) respectively. The steam pressure was adjusted between 1.5 kg/cm² to 2.0 kg/cm² in third stage according to observation of the body of product coming to third stage, from second stage. The milk flow rate was so adjusted to get the consistency required in the product. Homogenous mixture of final product was obtained from outlet of third stage which was collected in trays and spread into layer of uniform thickness. Then product was covered with aluminium foil and cooled at room temperature. When product got cooled, it was cut into pieces and analysed as explained below.

Measurement and Analysis

Analysis of milk

Initially the raw milk was tested for fat, SNF and total solids (TS) by Gerber method (IS: 1224, 1977) using lactometer.

Total solid (%) = SNF + Fat

Titratable acidity was determined using the method described in IS: 1479 (Part-I)-1960.

Analysis of khoa

Chemical analysis

The khoa manufactured using three stage SSHE by selecting process variables under consideration was analysed for Moisture/TS by gravimetric method as per IS: 2785 (1964).

Sensory Evaluation

The khoa made from fresh standardized buffalo milk have typical sensory attributes, which depends on the process variables under study, viz. steam pressure, rotor speed and mass flow

<table>
<thead>
<tr>
<th>Type</th>
<th>Gross Composition</th>
<th>Specific Sweets Prepared</th>
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<tbody>
<tr>
<td></td>
<td>Fat%</td>
<td>Moisture %</td>
</tr>
<tr>
<td>Pindi</td>
<td>21-26</td>
<td>31-33</td>
</tr>
<tr>
<td>Dhap</td>
<td>20-23</td>
<td>37-44</td>
</tr>
<tr>
<td>Danedar</td>
<td>20-25</td>
<td>35-40</td>
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</tbody>
</table>
rate. The khoa samples were subjected for sensory evaluation by a panel of 5-7 judges selected from Dairy Technology and Dairy Engineering Division. A 25-point descriptive scale was used for sensory attributes like Flavour, Body & Texture and Colour & Appearance.

**Texture Profile Analysis**
Analyser (Model TAXT2i, double cycle compression) of Stable Micro Systems, U. K., combined with Texture Expert Exceed Software, installed in Dairy Technology Division, NDRI, Karnal. Khoa was evaluated for various rheological properties like hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness.

**Process Parameters**
There are various process variables of three stage scraped surface heat exchanger that were selected for designed research project under study for manufacture of khoa:
- **Mass flow rate**: 170 - 210 kg/hr
- **First stage SSHE**
  - Pressure: 4.0 kg/cm²
  - RPM: 150, 175, 200
- **Second Stage SSHE**
  - Pressure: 2.0 kg/cm²
  - RPM: 125, 150, 175, 200
- **Third Stage SSHE**
  - Pressure: 1.5 to 2.0 kg/cm²
  - RPM: 15, 20, 25

The quality of khoa so produced was evaluated in terms of sensory scores, textural profile analysis and TS/Moisture

**RESULTS AND DISCUSSIONS**
In the present Investigation systematic attempt has been made to produce danedar khoa using thin film scraped surface heat exchanger. Product obtained was subjected to sensory evaluation using a panel of judges. Texture profile analysis was done by using a texture analyser. Instrumental texture profile analysis was used to compare the subjective sensory assessment of the textural attributes of the product. Based on these determinations, the operating parameter for formation of desired texture of the product has been optimized. The results obtained during present investigation are discussed in the proceeding text hereunder following heads:

**Preliminary Studies**
Initially trials were conducted using standardised milk of 5.5% fat and 9.0% SNF with different acidity levels (0.16, 0.17, 0.18, 0.19 %LA) by using SSHE and it was found that size and type of grains formed in final product was most suitable in case of milk with 0.18% LA. Acidity of milk was adjusted to predetermined value by using either natural souring by keeping it in unrefrigerated conditions for some time (if acidity was to be slightly raised) or by addition of small quantities of 10% citric acid solution in case acidity was to be raised substantially and measuring acidity after addition of citric acid solution. In no case milk was neutralised as milk received never exceed 0.16% LA initial acidity. In case of milk with 0.16 % LA there were no grains and product was pasty in texture and with loose body. As acidity was increased to 0.17 % LA there was small grain formation but in pasty texture. In case of 0.18 % LA there was good amount of grain formation desired in danedar khoa and also product was not pasty in texture. As acidity was increased to 0.19 % LA grains formed were much harder and of large size. The product was having acidic off flavour and also definite wheying off was observed in the product. Hence milk with 0.18 % LA was chosen for further studies for process optimization.

**Effect of Scraper speed on Sensory Attributes**
**Effect of Scraper speed on Flavour**
Fig.1 indicates the effect of scraper speed on flavour. It is evident that as scraper speed increases flavour scores decreases. It can be observed from graph that flavour scores are higher for lower speed in previous stage. This may be due to the fact that at the higher scraper speed, the residence time of the product in the SSHE is reduced which leads to less release of flavouring compounds at higher speeds.

**Effect of Scraper speed on Body and Texture**
Fig 2 indicates the effect of scraper speed on body and texture. It is evident that as third stage scraper speed increases body and texture scores decreases. It can be observed from graph that body and texture scores are highest when previous stage scraper speed is kept at 172.94 m/s and decreases on either side of 172.94 m/s circumferential velocity (150 rpm). Also the body and texture scores are lowest at lowest or highest
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Fig 1.1: Effect of rotor speed on flavour.
Fig 1.1: Effect of third stage rotor speed on flavour keeping first stage rotor speed at 200 rpm.
Fig 1.2: Effect of third stage rotor speed on flavour keeping first stage rotor speed at 175 rpm.
Fig 1.3: Effect of third stage rotor speed on flavour keeping first stage rotor speed at 150 rpm.

Fig 2.1: Effect of rotor speed on Body and Texture keeping first stage scraper at 200 rpm.
Fig 2.2: Effect of rotor speed on Body and Texture keeping first stage scraper at 175 rpm.
Fig 2.3: Effect of rotor speed on Body and Texture keeping first stage scraper at 150 rpm.
values of speed. This may be because at higher scraper speeds the grains formed are broken by blade at higher scraper speed, which results in a poor body and texture of the final product. The best results were observed at 172.945 m/s circumferential velocity for first and second stage scraper assembly.

**Effect of Scraper speed on Colour and Appearance**

As third stage scraper speed increases colour and appearance scores decreases. As first or second stage speed increases colour and appearance scores increases. It can be observed from graph that colour and appearance scores are higher for higher speed in previous stage. This may be because in third stage most of cooking occurs due to less speed and more residence time causing more color development which provides better color and appearance score with fall in third stage speed.

**Effect of Scraper speed on Overall Acceptability**

Fig 3 indicates the effect of scraper speed on overall acceptability. It is evident that as scraper speed increases overall acceptability scores decreases. It can be observed from graph that overall acceptability scores are highest when scraper speed is kept at 172.945 m/s and decreases on either side of 172.945 m/s. Also overall acceptability scores are lowest at lowest or highest values of scraper speed. This is obtained after summation of all three previous sensory scores hence it has all previous effects added linearly to give overall effect on acceptability of the final product.

**Effect of Scraper speed on Texture Profile**

**Effect of Scraper speed on Hardness**

It is evident from Fig 4 that as third stage scraper speed increases hardness decreases. As first
or second stage speed increases hardness also increases. It can be observed from graph that hardness is higher for higher speed in previous stage. This may be because as third stage scraper speed increases, the residence time of the product within the system decreases, resulting in higher moisture which lowers hardness of the final product. But in case of increasing scraper speed of first and second stage hardness decreases.

**Effect of Scraper speed on Gumminess**

Fig 5 indicates the effect of scraper speed on gumminess. It is evident that as third stage scraper speed increases gumminess decreases but as first or second stage speed increases gumminess also increases. It can be observed from graph that gumminess is higher for higher speed in previous stage. This may be because gumminess is product of hardness and cohesiveness hence gumminess varies directly as hardness does.

**Effect of Scraper speed on Chewiness**

Fig 6 indicates the effect of scraper speed on chewiness. It is evident that as third stage scraper speed increases chewiness decreases but as first or second stage speed increases chewiness also increases. It can be observed from graph that chewiness is higher for higher speed in previous stage. This may be due to fact that chewiness is directly proportional to hardness so it shows nearly same trends as hardness does.

**Effect of Scraper speed on Adhesiveness**

No particular trend is observed between scraper speed and adhesiveness. Hence we may assume adhesiveness to be uncorrelated to scraper speed. Adhesiveness of khoa made by SSHE is on higher side than that made by conventional method. This may be due to salt imbalance of the milk during processing in SSHE. It supports the argument of earlier workers that conditions should be standardized during processing.

**Effect of Scraper speed on Springiness**

No particular trend is observed between scraper speed and springiness. Hence we may assume springiness to be uncorrelated to scraper speed.

**Effect of Scraper speed on Cohesiveness**

No particular trend is observed between scraper speed and cohesiveness. Hence we may assume cohesiveness to be uncorrelated to scraper speed. The cohesiveness of the product made by SSHE was higher than that obtained from conventional method. It indicates that the extent of deformation of the product before it ruptures is higher in the case of SSHE than made by conventional method.

**Effect of Scraper speed on Overall Heat Transfer Coefficient**

Fig 7 indicates the effect of scraper speed on overall heat transfer coefficient. It is evident that as scraper speed increases overall heat transfer coefficient also increases. It can be observed from graph that U value is higher for lower speed in previous stage. This is be because increasing scraper speed increases turbulence and hence led to higher heat transfer rates. But increasing scraper speed in previous stage causes most of heat transfer to take place there only and much more concentrated and viscous product is delivered to next stage from which evaporation rate decreases due to high concentration and viscosity hence reduces heat transfer leading to comparatively lower overall heat transfer coefficient. Overall heat transfer co-efficient Value varied for first stage from 1431 W/m2K to 1775 W/m2K and for second stage it varied from 758 W/m2K to 1385 W/m2K and for third stage it varied from 126 W/m2K to 567 W/m2K.

**Effect of Scraper speed on Electric Power Consumption**

Fig 8 indicates the effect of scraper speed on electric power consumption. It is evident that as scraper speed increases electric power consumption also increases. It can be observed from graph that electric power consumption is higher for higher speed in previous stage. This is because increasing scraper speed increases work load on scraper motor and hence led to higher power consumption. But increasing scraper speed in previous stage causes more heat transfer to take place in that stage and much more concentrated and viscous product is delivered to next stage hence increasing density (due to rise in TS) of product so it becomes more heavy to be handled (scrapped and conveyed) and increasing power consumption. Electric power consumption for first stage varied from 360 to 480W and for second stage it varied...
Fig 4.1: Effect of Third Stage Scraper RPM on Hardness keeping First Stage Scraper at 200 RPM.
Fig 4.2: Effect of Third Stage Scraper RPM on Hardness keeping First Stage Scraper at 175 RPM.
Fig 4.3: Effect of Third Stage Scraper RPM on Hardness keeping First Stage Scraper at 150 RPM.

Fig 5.1: Effect of Third Stage Scraper RPM on Gumminess keeping First Stage Scraper at 200 RPM.
Fig 5.2: Effect of Third Stage Scraper RPM on Gumminess keeping First Stage Scraper at 175 RPM.
Fig 5.3: Effect of Third Stage Scraper RPM on Gumminess keeping First Stage Scraper at 150 RPM.
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**Fig 6:** Effect of Scaper RPM on Chewiness

- **Fig 6.1**: Effect of Third Stage Scaper RPM on Chewiness keeping First Stage Scaper at 200 RPM.
- **Fig 6.2**: Effect of Third Stage Scaper RPM on Chewiness keeping First Stage Scaper at 175 RPM.
- **Fig 6.3**: Effect of Third Stage Scaper RPM on Chewiness keeping First Stage Scaper at 150 RPM.

**Fig 7:** Effect of rotor speed on overall heat transfer coefficient

- **Fig 7.1**: Effect of Scaper RPM on Overall heat transfer coefficient keeping first stage at 200 RPM.
- **Fig 7.2**: Effect of Scaper RPM on Overall heat transfer coefficient keeping second stage at 175 RPM.
- **Fig 7.3**: Effect of Scaper RPM on Overall heat transfer coefficient keeping third stage at 150 RPM.
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**Fig 8.1**: Effect of Third Stage Scraper RPM on Electric Power Consumption keeping First Stage Scraper at 200 RPM.

**Fig 8.2**: Effect of Third Stage Scraper RPM on Electric Power Consumption keeping First Stage Scraper at 175 RPM.

**Fig 8.3**: Effect of Third Stage Scraper RPM on Electric Power Consumption keeping First Stage Scraper at 150 RPM.

*Plate 1*: Three Stage Scraped Surface Heat Exchanger (SSHE)
from 348 to 876W and for third stage it varied from 60 to 144W and for feed pump it varied from 228 to 300W.

**Energy consumption using SSHE**

Steam consumption for processing milk into danedar khoa using SSHE varied from 0.925 to 1.131 with an average of 1.017 kg steam used per kg of milk processed.

**Comparison between market sample and danedar khoa from SSHE**

**Selection of optimal operating parameter combination**

The optimal combination of operating parameter for production of danedar khoa with desirable textural attributes has been selected on the basis of overall acceptability of the product including all the sensory attributes of khoa. Hence optimum operating parameters for production of danedar khoa using SSHE are:

- **Initial Acidity of standardised milk** : 0.18% LA
- **Flow rate of milk through feed pump** : 190 kg/hr
- **RPM of First Stage SSHE** : 175 rpm (201.769 m/s)
- **RPM of Second Stage SSHE** : 150 rpm (172.945 m/s)
RPM of Third Stage SSHE : 15 rpm
(17.294 m/s)

Steam Pressure in First Stage SSHE : 4 kg/cm²
Steam Pressure in Second Stage SSHE : 2 kg/cm²
Steam Pressure in Third Stage SSHE : 1.5 kg/cm²
Values in brackets represent circumferential velocity or velocity at tip of scraper blade.

Comparative study
Comparative study was carried out with the market sample and danedar khoa made by using three stage SSHE with processing parameters as mentioned above. Table 2 represents comparison between the instrumental textural parameters of market sample and product made by using TFSSHE with 69.01 ± 1.89 percent total solid contents. All the textural parameters except hardness and adhesiveness of product made by using SSHE and market sample having around same total solid content were not significantly different from each other. Hence it is concluded that product manufactured from SSHE was comparable with market samples with exception that it was softer and more adhesive as compared to market sample.

<table>
<thead>
<tr>
<th>Instrument Textural Parameter</th>
<th>Danedar khoa from three stage TFSSHE</th>
<th>Market Sample (Danedar Khoa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (N)</td>
<td>25.209 ± 6.801</td>
<td>33.553</td>
</tr>
<tr>
<td>Adhesiveness (N.s)</td>
<td>-0.901± 0.553</td>
<td>-0.311± 0.389</td>
</tr>
<tr>
<td>Springiness</td>
<td>0.342 ± 0.115</td>
<td>0.349 ± 0.172</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.295 ± 0.095</td>
<td>0.222 ± 0.055</td>
</tr>
<tr>
<td>Gumminess (N)</td>
<td>7.451 ± 2.419</td>
<td>7.448 ± 3.304</td>
</tr>
<tr>
<td>Chewiness (N)</td>
<td>2.55 ± 1.099</td>
<td>2.59 ± 2.184</td>
</tr>
</tbody>
</table>

REFERENCES
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