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ORIGINAL ARTICLE

Heat penetration characteristics and physico-chemical properties of in-pouch processed dairy dessert (*kheer*)

Alok Jha · A. A. Patel · T. K. Srinivasa Gopal · C. N. Ravishankar

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Abstract *Kheer*, a traditional milk product of South East Asia, containing cooked rice grains in a creamy sweetened concentrated milk, has no large-scale production due to its poor shelf life. Shelf-life was improved by development of a process based on in-pouch thermal processing employing a rotary retort. Product development included optimization of rice-to-milk solids ratio (0.18–0.52) and total milk solids levels (16–26 %) to simulate the conventional product in taste, appearance and textural attributes. Various F_o values (12.4–14.8) were examined with regard to product quality. While the TBA value tended to increase (0.073–0.081) the reflectance value (35.3–43.4) declined with increasing F_o. The pH of the product (6.04–6.10) showed a slight tendency to increase with F_o. Sensorily, the product was found to be acceptable for a period of 150 days at 37 °C.

Keywords In-pouch processed *kheer* · Rotary retort · TBA value · F_o value · Rice-to-milk solids ratio

Introduction

The manufacture of indigenous milk products is confined mainly to the non-industrial sector in India. It is reported that about 50 % of milk produced in the country is converted into numerous sweets and desserts, which are deep rooted in ancient traditions and have a strong cultural heritage. One such product is known as *kheer.* It is a semi-solid to fluid dairy product with partially disintegrated cooked rice grains dispersed in viscous liquid comprising of soluble starch from rice grains (Rangappa and Achaya 1974). Conventionally prepared *kheer* has a dark creamish colour as a result of prolonged cooking of rice grains in milk, which normally takes approximately one hour depending on the type of rice and the quantity of the product required to be made. *Kheer* is made by concentrating milk with simultaneous cooking of rice grains and addition of sugar during the process (De et al. 1976). Shelf life of *kheer* is very poor and even under refrigeration, it does not keep well for more than two days (Singh et al. 1987). In spite of its religious value, nutritional significance and commercial potential, manufacture of *kheer* remains confined to domestic kitchens. One of the reasons for the lack of its organized manufacture and marketing is poor shelf-life and lack of technology for large-scale manufacture. In the past, attempts have been made, though with only a limited success, to enhance the shelf-life of *kheer* by means of preservatives such as nisin and sodium metabisulphite (De et al. 1976; Singh et al. 1987; Eapen et al. 1988). Attempts have also been made to modify the conventional *kheer* making process in order to have a more uniform product (Srivatsa et al. 1993). Similar to *kheer*, a canned dairy dessert called 'creamed rice' with a shelf-life of 12 months has also been reported (Keogh 1970). A milk-wheat based *dalia* dessert processed in a rotary retort using tin-free steel cans with a shelf life of 72 days at 37 °C has also been reported by Jha et al. (2012). Among several methods of processing and preserving foods, thermal processing, especially use of retort pouches, has several advantages over tin cans. Consumption of canned foods is declining (Nair and Girija 1994; Dileep and Sudhakara

A. Jha (✉)
Department of A. H. & Dairying, Banaras Hindu University,
Varanasi 221 005, India
e-mail: alok_ndri@rediffmail.com

A. A. Patel
Dairy Technology Division, National Dairy Research Institute,
Karnal 132 001, India

T. K. S. Gopal · C. N. Ravishankar
Central Institute of Fisheries Technology,
Kochi 682 029, India

2007) due to high cost of tin for making cans acceptable to the market (Srivatsa et al. 1993). Retort pouch can be imprinted, its shape and size is flexible, and can be very well displayed on shelves. Food can be cooked faster in flexible pouches than in tin cans due to faster heat transfer rates. It also helps in reducing the cost of delivery and storage of food products (Dushyanthan 2002). Retortable pouches have been used in the past for several food products such as Kerala style fish curry (Gopal et al. 2001), seer fish curry (Shankar et al. 2002), tuna in oil (Ali et al. 2006), ready-to-eat pearlshot fish curry (Pandey et al. 2007) and prawn *kurma* (Mohan et al. 2008).

In view of the immense possibilities which the thermal processing using retortable pouches offers for newer food products with long-shelf life, present work was undertaken with the following objectives: to study the effect different F_o values on the shelf life of *kheer* as compared to just one to two days to promote its transportation and marketing and also to develop a proper package i.e. retort pouch for the product, which hitherto has been marketed without any packaging. This paper discusses the physico-chemical properties, heat penetration characteristics and sensory properties of in-pouch processed *kheer* as influenced by various formulation and processing parameters.

Materials and methods

Materials

Milk was obtained from the Ernakulam Co-operative Milk Producers' Union Ltd., Kochi (India) and it contained 3.0 % fat and 8.5 % SNF. Rice used in the present investigation was obtained from Chaman Lal Rice Exporters Ltd., Karnal, India ensuring commercially pure variety of Basmati (3/4 brokens). Cane-sugar procured from the local market of Kochi (India) was used. BHA used as an anti-oxidant in long-life *kheer* was procured from the Sigma Chemical Co. (St-Louis, MO, USA).

Retort pouches

Retort pouches made of polyester/aluminium/polypropylene laminate for in-package processing of long-life *kheer* were obtained from M/s MH Packaging, Ahmedabad, India. These rectangular (12 cm×15 cm) pouches had a thickness of 115.0 μ (15.0 μ polyester, 12.5 μ aluminium foil and 87.5 μ polypropylene).

Processing equipment

For experiments on process development for long-life *kheer*, the pilot-scale Millwall Model 24 Rotary Retorting System (John Fraser Co., UK) was used. The retort with a rotary square-cage was operated in the steam–air mixture mode for sterilization. It was set at 121.1 °C, with a steam pressure of 1.05 bar and an overpressure of 2.1 bar was maintained during each process cycle. The retort was used in rotary mode with cage rotation speed of 2 rpm.

Product formulation

Variables for product formulation included total milk solids (TMS) in pre-concentrated milk and rice-to-milk solids (RMS) ratio. Sugar was used at the rate of 12 % of milk. Three levels of TMS were used namely 16-17 % (low), 22–23 % (medium) and 25–26 % (high) for the rice-to-milk-solid ratio ranging from 0.18 to 0.52.

Production of long-life *kheer*

A detailed flow chart for the manufacture of in-pouch processed *kheer* is given in Fig. 1. As compared to this, conventional *kheer* was made in open steam kettles by slowly cooking rice grains in milk for around 1 h with the addition of sugar in the middle of the cooking process. In-pouch temperature and time profile was monitored during the complete sterilization cycle (Patashnik 1953). F_o values were provided by the computer using the Ellab software as discussed in detail separately.

Chemical analysis of long-life *kheer*

Twelve lots of long-life *kheer* produced with process times corresponding to F_o values of 12.4, 13.2 and 14.6 (in quadruplicates) were stored at 37 °C and monitored for TBA value, reflectance and pH for a period of 5 months. The contents of a *kheer* pouch were subjected to vacuum filtration using plastic sieve (14 square holes per cm) held in a ceramic filtration funnel to separate the particulate rice mass or the solid fraction from the liquid phase. The rice (particulate) phase and the liquid phase were separately analyzed. Also *kheer* from another pouch was ground in a Sumeet mixer (SP-16 Electronic Model, India; wet grinding blade-speed code: Red) for 5 min. The colour of the liquid phase of stored *kheer* was measured in terms of reflectance value using a reflectometer with an exposure unit (search unit) (CL-28, Elico Pvt. Ltd., Hyderabad, India) fitted with a 450 nm filter. The instrument was standardized using a standard plate with a reflectance value of 50. The sample (tempered at 25 °C for 3 h) was transferred into a 200 ml dilution bottle leaving no headspace. It was placed under the search unit and reflectance value read out (in %) at 10 different places on the bottle and the average taken as reflectance value. The extent of oxidation of fat in the product was measured in terms of Thiobarbituric acid (TBA) value

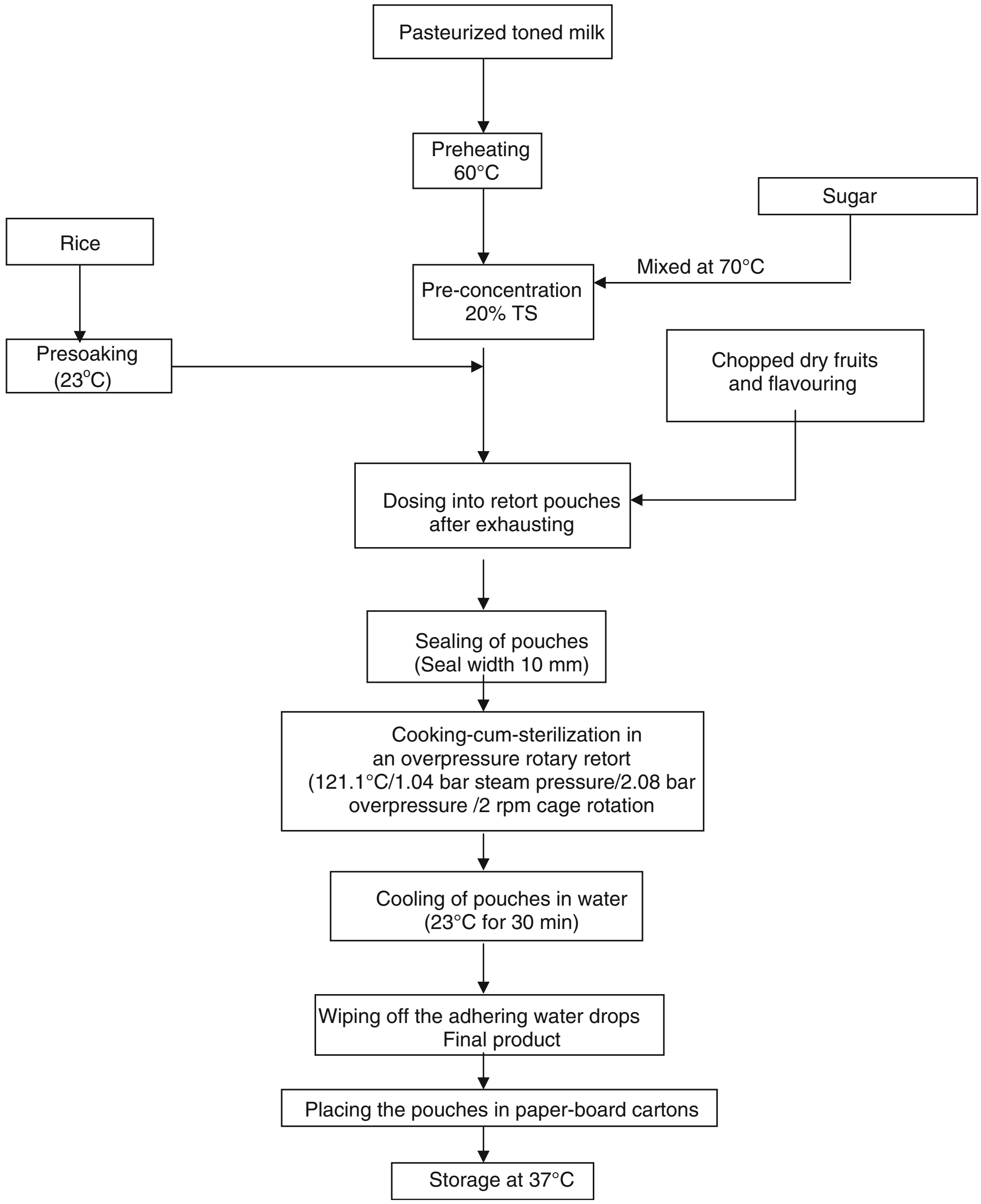

Fig. 1 Schematic diagram for the manufacture of retort processed *kheer*

and using 90 g of ground *kheer* prepared as per the procedure given by Sidwell et al. (1955). TBA was expressed as optical density (OD) take at 530 nm. The pH was measured at 25 °C by a microprocessor controlled pH meter (Labindia Instruments Pvt. Ltd., Mumbai, India) fitted with an Orion gel-filled combined electrode.

Generation of heat penetration data

For every production trial, two of the pouches, transferred to the retort were fitted with thermocouples for measurement of the product temperature every 30 s during the process. A specially designed packing gland (Type GTK-21009-C000, ELLAB Co. Denmark) was used to enable the penetration of thermocouples into the retort pouch. Sets of thermocouple wires placed inside the pouch and the retort were linked to a precision data logging device (Model CTF 84, ELLAB Co., Denmark) which was capable of converting the temperature input data into corresponding process lethality values. These process lethality values were expressed as F_o values.

Construction of a heat penetration curve

Heat penetration data were plotted on a semi-logarithmic paper. While F_o value was obtained from the software used along with the data logger, the following formula was employed to calculate the sterilization time (U defined as the equivalent, in minutes at retort temperature, of all lethal heat received during the process) at 121.1 °C:

$$U = F_o \cdot 10\frac{(121.1 - T)}{z} \qquad (1)$$

where

T Set retort temperature (°C)

z 10 °C for *Clostridium botulinum*

The thermal process time (B) i.e. time in minutes, when no time is required to bring the retort to processing temperature, was calculated, as per the procedure suggested by Patashnik (1953):

$$B = f_h(\log J_h \cdot ID - \log\ g) \qquad (2)$$

where

B process time to achieve final temperature deficit

g final temperature deficit at the end of heating obtained from f_h/U: g and J_c tables.

Total process time (B') was calculated by adding to 58 % of the come-up time to B.

Sensory evaluation

Five lots of long-life *kheer* (TS: 32.5–34.0 % and RMS ratio: 0.36–0.40) stored at 37 °C were subjected to sensory evaluation for a period of 5 months. Sensory evaluation of long-life *kheer* was performed by a panel of 9 trained judges from the faculty of the Dairy Technology Division at National Dairy Research Institute, Karnal. A special laboratory with necessary facilities viz., separate booths, provisions for adequate diffused light and air-conditioned odour free environment was employed for product evaluation. Hedonic rating (9-point scale) was used for colour, texture, flavour and overall acceptability of the conventional as well as long-life *kheer*.

Statistical analysis

Data obtained from the various experiments during standardization process and storage studies of long-life *kheer* were subjected to analysis of variance (ANOVA) as described by Snedecor and Cochran (1994). All the experiments were conducted in triplicate.

Results and discussion

Physico-chemical properties of long-life *kheer*

Results of physico-chemical properties of long-life *kheer* and the influence of F_o values are presented in Table 1. pH of long-life *kheer* varied from 6.04 to 6.10. It appeared to increase with increasing F_o value (r=0.90, $P<0.01$). This lower than the normal pH (as compared to milk) may be attributed to the concentration of milk and the heat treatment given to the product in the retort. However, the increase in pH with the intensity of heat treatment was inexplicable. An interaction between the rice components and milk system could be one of the possible reasons. The TBA value of long-life *kheer* ranged from 0.073 to 0.081. It appeared to be directly related to the process lethality value (F_o). TBA value was higher in products that received a higher heat treatment. This could be because TBA is also a measure of the generation of TBA reactive products, which depends on extent of heat treatment. The reflectance

Table 1 Physico-chemical properties of long-life *kheer* made with different process lethality values

F_o	pH[a]	TBA value[a] (OD at 530 nm)	Reflectance value[b] (at 450 nm)
12.4	6.05	0.073	43.3
12.5	6.04	0.075	43.2
12.6	6.06	0.075	43.2
12.8	6.04	0.075	42.5
12.9	6.05	0.076	42.3
13.0	6.07	0.074	41.3
13.2	6.07	0.075	40.8
13.4	6.08	0.078	40.9
13.5	6.08	0.079	40.7
13.7	6.08	0.079	39.4
14.5	6.09	0.080	36.4
14.6	6.09	0.076	38.0
14.8	6.10	0.081	35.3

[a] n=3

[b] Measured on the liquid phase of the products

value for the long-life *kheer* declined perceivably as the F_o value increased, the correlation (r=−0.97) being highly significant ($P<0.001$). It ranged from 35.3 to 43.3 and was indicative of the fact that the degree of browning of the product increased as the retort process time increased. The colour of long-life *kheer* was considerably dark ('definite browning') in comparison to the colour of the conventional *kheer* ('slight browning'). This difference could be attributed to the high process lethality values (F_o) for making long-life *kheer*.

Heat penetration characteristics of long-life *kheer*

Lag period for heating curve (j_h)

Thermal process parameters of long-life *kheer* are presented in Table 2. The j_h value given as pseudo-initial temperature deficit (PID) divided by the actual initial temperature deficit (ID) ranged from 0.44 to 1.17. The *kheer* mix comprising of rice and sugar, subjected to thermal processing could be considered as essentially a liquid product and the mode of heating could be said to be convective. For purely convective packs, there is little or no lag period (i.e. the come-up time is very short); hence, PID and ID coincide, so that j_h is equal to 1.0 (Jones 1968). However, in actual practice, there is always some gap in time period before a product could reach the retort temperature, leading to differences in come up time depending on the composition, size etc. and hence, to variations in j_h value. The variations observed in the present study, however, could not be related to the product's composition in terms of TS or RMS ratio. Condensed cream of celery soup was reported to have a j_h value of 1.3 (Berry and Bradshaw 1982). Products heated under agitation have large j_h values, but it takes some for the viscous forces of the product to be overcome by the inertial forces induced by the rolling of the can (Berry and Bradshaw 1980). j_h value for retort processed *dalia* dessert was reported to be in the range of 0.40 - 0.85 indicating a convective heating regime (Jha et al. 2012).

Heating rate index (f_h)

The time taken for a heat penetration curve to traverse one log cycle is called the f_h value. In the present study, f_h values were in the range of 2.82 to 8.70 min. These values are in the range of the values reported for convection heating products, in contrast to conduction heating products whose f_h values are reportedly 15 or more times than this viz. 30–40 min (Horner 1992). Heating rate index (f_h) for convective heating products has been reported to be dependent upon temperature of heating medium and condensing surface, steam–air flow rate and direction, surface size and orientation, viscosity, film thickness and stagnant air layer thickness (Tung et al. 1990). Compared to conduction-heating products, convection heating products have a large heat capacity and thermal diffusivity, and reach retort temperature very quickly after which they remain essentially inert with respect to heat transfer (Weintraub et al. 1989). The f_h value for mushrooms in brine was also found to be in the

Table 2 Thermal process parameters[a] of long-life *kheer*

Trial No.	TS/RMS	Parameters					
		j_h	f_h	j_c	B	F_o	C_g
1	41.8/0.21	1.17	2.82	2.31	15.66	12.4	76.2
2	36.2/0.28	0.45	5.65	1.40	20.05	13.2	84.1
3	33.8/0.32	0.90	6.40	1.06	21.52	14.6	90.5
4	29.2/0.18	0.47	3.55	1.31	16.19	13.0	78.3
5	30.6/0.30	0.81	4.40	1.18	18.29	13.7	83.2
6	30.6/0.40	0.57	4.10	1.51	15.77	12.9	76.4
7	37.9/0.18	0.52	4.30	1.10	14.89	13.4	87.1
8	39.0/0.24	0.51	6.30	1.16	19.65	14.8	96.5
9	39.3/0.29	0.44	4.10	1.50	15.53	12.6	80.4
10	32.8/0.31	0.88	5.50	1.09	21.08	14.5	93.0
11	33.4/0.43	0.79	5.44	1.40	19.13	13.5	84.1
12	34.4/0.52	0.69	5.72	1.37	18.71	13.4	87.7
13	34.0/0.36	0.98	5.40	1.09	18.59	12.5	79.7
14	33.1/0.39	0.73	6.40	1.29	19.87	13.0	85.9
15	32.9/0.39	0.79	8.70	1.92	18.32	12.8	87.0
16	32.5/0.40	0.47	6.50	1.51	18.75	13.7	86.9

[a] $n=3$

TS Total solids in milk; *RMS* Rice to milk solids ratio range of 4.7 to 5.8 min depending on the can size and weight of the product (Berry and Bradshaw 1982).

Lag factor for cooling curve (j_c)

Lag factor in cooling curve occurs because the product temperature does not fall as rapidly as the retort temperature falls. j_c values for convective heating products are reported to be close to 1 and for conducting heating packs j_c values could be much higher as the cooling process is much slower for these products. j_c values for the pre-mix of long-life *kheer* ranged from 1.06 to 2.31, which were in conformity with the values reported for convective heating liquid products (Horner 1992).

Process time (B)

The total process time (B) and operator's process time (P_t) depend greatly on f_h and j_h values obtained for each process. B value for *kheer* ranged from 14.89 to 21.52 min depending on the F_o value (12.4–14.8) and related factors. Process time for products heated in conduction-heating regime are generally very long as compared to the ones observed in this study (Thijssen et al. 1978). The low process time coincided with the low values for f_h and j_h for the convection heated *kheer* as compared to conduction heated products. Process time for soybean paste and soybean in brine at 121.1 °C were 25 and 18 min, respectively (Guedez and Bath 1975). Pouch thickness affects the process times. Pflug et al. (1963) demonstrated a three-fold reduction in the process time necessary to achieve an F_o of 9 min simply by reducing the pouch thickness from 25.4 to 6.4 mm. Mango juice had a process time of 45 min corresponding to an F_o of 11.0 (Nanjundaswamy et al. 1973).

Cook value (C_g)

While process value (F_o) may be defined with respect to the effect of exposure time at a specific temperature on a specific organism, cook value (C_g) encompasses a multiplicity of physical and biochemical changes. Cook value (reference temperature, 100 °C and z value, 33 °C) for long-life *kheer* ranged from 78.3 to 96.5 min. It increased or decreased with an increase or decrease in F_o value (Table 2). Such a large cook value was expected to result in extensive softening of rice grains, but it did not so happen, and the grains were rather tough. It could be because the rice grains after gelatinization underwent retrogradation during cooling process resulting in softer grains. However, the product, as anticipated, underwent considerable browning.

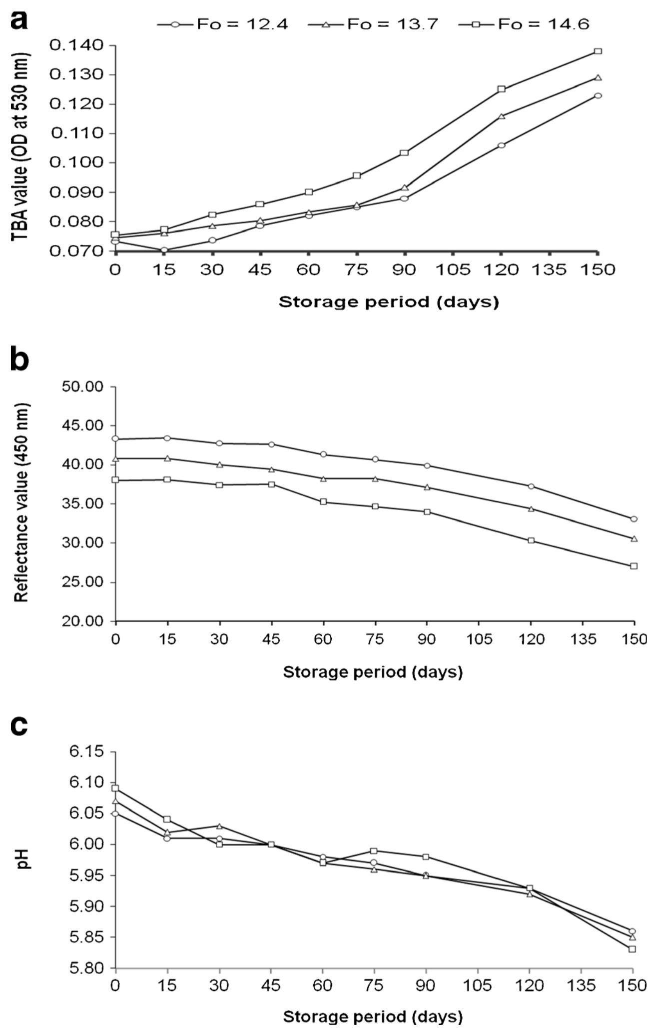

Fig. 2 **a** Thiobarbituric acid (TBA) value (OD value at 530 nm), **b** Reflectance value (450 nm) and **c** pH of long-life *kheer* as influenced by F_o value and period of storage at 37 °C (values are mean of triplicate experiments)

Effect of process lethality (F_o value) on physico-chemical properties of stored long-life kheer

Data presented in Fig. 2a show that the TBA value increased during the storage at 37 °C, the increase being rapid after 90 days and was generally higher in formulations with higher process lethality values. For the formulations receiving heat treatment equivalent to F_o of 12.4, the TBA value increased from initial 0.073 to 0.123 at the end of storage, while for formulations with F_o of 13.7 and 14.6, the respective increases were from 0.075 to 0.129 and 0.076 to 0.138. However, statistical analysis of the data (Table 3) revealed that only the effect of storage period was significant ($P<0.01$); the TBA value was significantly higher after 120 days of storage. It thus appeared that fat oxidation took place during storage of the product. Use of antioxidant (0.01 % BHA) did not make any perceivable difference in the TBA

Table 3 Analysis of variance: Changes in physico-chemical properties of long-life *kheer* during storage

Source of variation	DF	TBA		Reflectance		pH	
		F -ratio	CD	F -ratio	CD	F –ratio	CD
Replicates	3	1.70^{NS}		2.63 ^{NS}		1.51 ^{NS}	
Storage period	8	2.01**	0.040	9.87 **	2.97	27.75 **	0.089
Treatment (F_o value)	2	0.52 ^{NS}		18.25 **	1.71	0.82 ^{NS}	
Interaction (treatment x period)	16	1.62 ^{NS}		0.57 ^{NS}		0.33 ^{NS}	
Error	51						

CD Critical Difference; *NS* Not significant

**$P<0.01$

value (0.114 with the antioxidant and 0.124 without the antioxidant). TBA value of UHT soy beverage increased from 0.068 (OD) to 0.199 (OD) after 10 days of storage at 45 °C (Narayanan et al. 1993). Changes in the reflectance value of in-pouch processed *kheer* during storage at 37 °C are presented in Fig. 2b. It can be seen that formulations with a higher F_o had a lower reflectance value as compared to formulations with a lower F_o and the values declined in all the samples during storage. The reflectance value for the products with F_o of 12.4 decreased from the initial 43.30 % to 33.05 % after 150 days of storage. The corresponding values were 40.77 and 30.55 % for F_o of 13.7, and 38.01 and 27.02 % for F_o of 14.6. Statistical analysis (Table 3) showed that the effects of both the storage period and F_o value had a significant effect on the reflectance value ($P<0.01$). Thus, browning of the product was significant after 75 days in products of F_o 12.4 and 13.2, and after 60 days in that of F_o 14.6. Product with higher F_o was accompanied by greater browning as observed during the entire storage period. Reflectance of UHT soy beverage dropped from 52.3 % to 49.5 % after 10 days of storage at 45 °C (Narayanan et al. 1993). Singh and Patil (1989) also reported a similar decrease in reflectance of UHT milk during storage and attributed it to the non-enzymatic browning reactions. The effect of storage on pH of long-life *kheer* made with different F_o values is shown in Fig. 2c. It is clear that the storage led to a significant decrease in pH of all the formulations. pH declined from the initial values in the range of 6.05–6.09 to 5.83–5.86 at the end of storage. The F_o value, however, had no significant effect on pH (Table 1). This decrease in pH, could be attributed to the Maillard reaction, taking place during storage leading to the production of organic acids. A similar drop in pH of sterilized soy beverage during storage has also been reported by Tomar and Chauhan (1988).

Sensory properties of long-life kheer

Sensory properties of long-life *kheer* both when it was fresh and after storage upto 150 days at 37 °C are presented in Table 4. It can be seen that colour score decreased from 6.92 to 4.72 after 150 days. Poor colour scores could be attributed to high F_o values. Texture score declined from 8.00 to 6.72 after storage till 150 days. Texture scores of in-pouch processed product were comparable to that of conventional *kheer*. There was a decline on flavour score from an initial value of 7.26 to 5.92 after 150 days of storage. This could be attributed to increase in oxidative rancidity during storage. In-pouch processed *kheer* was almost comparable to conventional product in terms of overall acceptability rating. However, its overall acceptability declined from 7.54 to 5.77 at the end of storage studies. This could be expected in a product which will undergo deterioration during storage in terms of colour and flavour.

Conclusion

Perceiving the potential of *kheer* as a value-added product in the International dairy market, ready-to-serve milk-rice *kheer* was developed employing a rotary retort system. The in-pouch processed product had a commercially useful shelf life of 5 months without refrigeration. Total process time (B value)

Table 4 Sensory properties of long-life *kheer* in comparison to conventional *kheer* and effect of storage

Properties (on 9-point hedonic scale)	Conventional *kheer*	Long-life *kheer* 0 day	Long-life *kheer* 150 day	CD ($p<0.05$)
Colour score	8.5±0.15	6.9±0.17	4.7±0.21	0.50
Texture score	9.0±0.00	8.0±0.11	6.7±0.17	0.30
Flavor score	8.5±0.15	7.3±0.09	5.9±0.15	0.39
Overall acceptability score	8.5±0.15	7.5±0.13	5.8±0.16	0.21

[a] $n=7$ panelists

CD Critical difference

for long-life *kheer* ranged from 14.89 to 21.52 min depending on the F_o value (12.4–14.8). F_o values employed in manufacturing had a profound effect on product properties such as pH, TBA value and colour. pH of long-life *kheer* varied from 6.04 to 6.10. TBA value of long-life *kheer* ranged from 0.073 to 0.081. As the product could be stored upto 5 months at ambient temperature without any appreciable loss in terms of chemical and sensory attributes, it could be used as a potential means of product diversification in the dairy industry.

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