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Effect of process parameters on hardness of rice for *kheer* prepared using mechanized system

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Abstract
In the present study *kheer* was prepared using mechanized system comprising of Conical Process Vat (CPV) and Scraped Surface Heat Exchanger (SSHE). Effect of process variables total solids of concentrate from SSHE (20, 22, 24% TS) and CPV steam pressure (1.5, 2.0, 2.5 kg/cm^2) on hardness of rice grain was studied. Statistically (p<0.05) meaningful relations were obtained between processing parameters: CPV steam pressure, total solids of milk concentrate (TS) obtained from SSHE and hardness (N) of cooked rice grain. The hardness showed the negative and positive co-relation with TS% and CPV steam pressure respectively. The maximum value of hardness (5.27 N) was observed at 2.5 kg/cm^2, 28% TS while the lowest value (2.8 N) was observed at 1.5 kg/cm^2, 20% TS. The study established showed it is possible to get desired hardness of rice grains by setting the process parameters.

Keywords: *Kheer*, hardness, mechanized system, conical process vat, scraped surface heat exchanger

1. Introduction
The hydro-thermal processing of rice has become one of the most widespread food industries of the world since it constitutes a major partof the global nutritional need for carbohydrates (Bello, Tolaba & Suarez, 2007; Bhattacharya, 1990; Van dev Doel *et al*., 2009; Kadam *et al*, 2013) [2, 3, 28, 15]. In Indian sub-continent cereals have been incorporated in milk since long ages to make the heat desiccated products like *kheer, sevian,* etc. Such form of supplementation has number of benefits like to increase the added nutritional value and to provide certain technological functions in food processing (Jalal *et al*., 2016) [13]. The conversion of milk to indigenous product not only adds to its nutritional value but also makes it more profitable. *Kheer* is a heat-desiccated cereal-based sweetened, condensed and nutritious Indian dairy dessert (Jha *et al*., 2013) [14]. It is generally made of milk and rice. It is prepared by cooking rice with sugar or jaggery in milk till the point when rice starch gets gelatinized (Aneja *et al*., 2002; Gupta *et al*., 2014; Jha *et al*., 2013; Singh *et al*., 2017) [1, 11, 14, 26].
The textural attributes are of prime importance to eating quality of cereal based food (Ong & Blanshard, 1995) [21]. Texture is a multi-parameter sensory property, with hardness and stickiness as the most commonly determined parameters for cooked rice (Patindol *et al*., 2010) [22]. In addition to sensory evaluation by human panels (subjective test), textural properties of cooked rice are most commonly measured by instruments such as a textural analyzer (objective test) (Cameron and Wang, 2005; Champagne *et al*., 1998) [5, 6]. In the present study, focus has been made to study the effect of processing parameters on hardness of rice grain of *kheer*. Less time for cooking results in excessive hard grain while over cooking tends to increase viscosity with more breakage of rice grain. After processing many other changes like starch retro-gradation, loss of flavour/aroma and colour, decreased adhesiveness may occur during cooling of product (Yu *et al*., 2009) [29]. More recent studies suggested that the long B chains of amylopectin, which were strongly positively correlated with the insoluble amylase content, were the key determinant of rice texture (Cameron and Wang, 2005) [5]. Long B chains in amylopectin strengthened the starch granules through intermolecular interaction, leading to a firm texture of cooked rice (Chinnaswamy and Bhattacharya 1986; Takeda *et al*., 1987; Hizukuri *et al*., 1989; Radhika-Reddy *et al*., 1993; Ong and Blanshard 1995; Ramesh *et al*., 1999) [7, 27, 12, 23, 21, 24]. In the present study *kheer* was prepared using mechanized system comprising of Conical Process Vat (CPV) and Scraped Surface Heat Exchanger (SSHE). Effect of process variables total solids of concentrate from SSHE (20, 22, 24% TS) and CPV

steam pressure (1.5, 2.0, 2.5 kg/cm^2) on hardness of rice grain was studied.

2. Materials and Methods

2.1 In-line system

In-line system was developed for mechanized production of multiple traditional Indian dairy products. The basic configuration of in-line system iss scraped surface heat exchanger and conical process vat. As per need cooling system, product transfer system, butter melter etc can be integrated to the in-line system. The setup was arranged in a way to facilitate rapid concentration of milk in SSHE. Final cooking of rice and concentrated milk was completed in conical process vat. The similar arrangement was used by Dodeja *et al*. (2012) [25] for manufacture of *basundi*. The high grade basmati rice (Kohinoor Foods Ltd., India) was used for dessert preparation. The rice was pre-soaked at the temperature of 80 ºC for 10 min in steam kettle and then was further used for *kheer* preparation.

2.2 Single stage scraped surface heat exchanger

In scraped surface heat exchanger, the liquid product is spread over the heating surface by rotating blades. Each cycle of scraper blade lifts and spreads the liquid along the heat exchanger surface. In the mean time blades scrape the surface to remove the solid deposits and prevent fouling. The characteristics of scraped surface heat exchanger are: high heat transfer coefficient, low residence time distribution, minimum surface fouling and can be used for viscous products. In the in-line system, scraped surface heat exchanger is used for intensive heat treatment and fast evaporation (Minz *et al*., 2013) [20]. Scraper was driven with a 1.5 hp motor (1400 rpm) and a speed reduction gearbox. Scraper speed was controlled (0-200 rpm) by variable frequency drive (VFD). Other components of SSHE were vapour vent, vent cock, steam trap, air vent and safety valve. In SSHE, steam is made to pass through the annular space between two cylinders while working liquid is supplied to the annular space between the rotating shaft and inner cylinder.

2.3 Conical process vat

The second major equipment is conical process vat (CPV). It is a mechanized vat with conical configuration of straight scrapping profile with a cone angle of 60°. Steam jacket is partitioned into four independent segments for efficient use of thermal energy and less heat loss. The mechanism consists of 3-equidistant arms supported at two points in the shaft and each arm having three independent spring loaded blades for scraping. A backward racked, 3-vaned impeller for continuous product discharge has been mounted on the central shaft. The unit has a positive displacement screw pump for recirculation and spreading of product during processing for texture control and increased heat transfer. CPV can be used for mixing, simmering (slow heating) and heating (with & without agitation). CPV with variable heating surface allows better control over heating (Minz *et al*., 2013) [20]. In-line system has been successfully used for production of *rabri* (Chopde *et al*., 2013; Chopde *et al*., 2016) [9, 8], *khoa* (Kumawat *et al*., 2012; Khojare & Kumar, 2003) [17, 16] etc.

2.4 Kheer preparation

In unit operation based process modification Scrapped Surface Heat Exchanger (SSHE) was used for manufacture of *kheer*. SSHE steam pressure was kept at 4 kg/cm^2 with 200 rpm scraper speed. Flow rate of feed to the SSHE was kept at 150 kg/h. For manufacture of *kheer*, buffalo milk was standardized to 6.0% fat and 9 % SNF. Milk was concentrated in SSHE up to desired concentration (20, 22 & 24%) and was transferred to Conical Process Vat (CPV) through pump installed in the transfer line. Pre-soaked basmati rice was added at the rate of 5% and was cooked along with concentrated milk in CPV at different steam pressures (1.5, 2.0, 2.5 kg/cm^2) with gentle agitation/scraping till concentration reaches to 32%. After that sugar was added at the rate of 5%.

2.5 Texture analysis

Hardness (N) of the individual cooked rice grain was measured using Texture Analyzer (Model - TA-XT2i, Stable Micro Systems, Godalming, UK). Borad *et al*. (2017) [4] used the texture analyzer to find the effect of storage and heating on texture of rice grain in dairy dessert. Similarly Li *et al*. (2016) [19] used texture analyzer for texture profile analysis (TPA) of cooked rice grain. The instrument was calibrated at the test conditions, 5 mm rice grain specimen length, 2.0 mm/s pre-test speed, 1.0 mm/s test speed, 2.0 mm/s post-test speed with single-bite compression till with 80% of original of original cooked grain thickness. P-75 (Aluminium) compression probe was used with 10 specimen of each sample. Analysis of sample and graphs were obtained using the software.

2.6 Statistic Analysis

The results were analyzed as general Factorial model using Design Expert Software trial version 11.0 (Stat-Ease Inc., USA) in relation to process parameters viz., TS% milk concentrate SSHE and CPV steam pressure. The data was tested for normality using shapiro wilk (w test; $p<0.05$).

3. Results and Discussions

The hardness of rice grain was significantly affected by TS% and CPV steam pressure ($p<0.05$%). It was observed that the TS% of milk concentrate obtained from SSHE is negatively correlated with hardness as it decreased with increase in TS% when at constant CPV steam pressure. The CPV steam pressure was found to be positively correlated at constant TS%. This effect can be seen from the equation (1) mentioned below. The lower steam pressure caused the increase in processing time, due to which rice grain might have absorbed more water and swell. This granule expulsion causes rupture of grain leading to a decrease in hardness (Li *et al*., 2016) [19]. Also there is well-documented evidence that amylose and amylopectin molecules leach into the surrounding water above the gelatinization temperature (Cuevas *et al*., 2010). These leached amylose and amylopectin molecules are likely to contribute to stickiness of cooked rice and decrease in hardness (Leelayuthsoontorn & Thipayarat, 2006; Li *et al*., 2016) [19]. The hardness (N) curves of rice grain (one sample out of 10 replications) obtained using texture analyser (Model -TA-XT2i) at combination of various TS% and CPV steam pressure are shown in fig. 2-3. It was observed that with increase in TS%, hardness (N) increased. The maximum value of hardness (5.27 N) was observed at 2.5 kg/cm^2, 28% TS while the lowest value (2.8 N) was observed at 1.5 kg/cm^2, 20% TS.

The effect of factors interaction was observed which behaved differently. When CPV steam pressure increased there was an increase in hardness. This is due to decrease in processing time in CPV which was due to the fact that 1.5, 2.0, 2.5 kg/cm^2 steam pressure corresponds to 111, 120, 126.5 ºC temperature respectively. It means less time taken for the moisture evaporation at high pressure and hence less time for chemical reaction with the surface of rice grain to attain final concentration 32% TS thus hardness decreases as CPV pressure increases.

Analysis of variance of factors (ANOVA) and interactions reveals the model F-value was 429.17 which is much higher for the model to besignificant ($p<0.05$) and there is only a 0.01% chance that an F-value this large could occur due to noise or unknowing errors. Probability plot in fig. 4 shows how the data points lies around the line of best fit. R^2 value for the model was found to be 0.994 and the adjusted R^2 value was 0.992. Following equation (Eq.1) can be used to predict hardness value on the basis of process variables:

$$\text{Hardness} = 4.13 - 0.9279A^1 + 0.23\,A^2 - 0.2997B^1 + 0.0388B^2 + 0.0787A^1B^1 - 0.0013A^2B^1 + 0.0684A^1B^2 + 0.0732\,A^2B^2 \quad \text{Eq. (1)}$$

4. Conclusion

This study focused the effect of TS% and CPV steam pressure on the hardness (N) attribute of rice grain during *kheer* preparation. Hardness value (N) with respect to TS% and CPV steam pressure provides enough information which is helpful during in in-line unit operation based manufacturing of rice *kheer*. Hence the quality of *kheer* like rice hardness can be controlled by selecting the combination of process parameters. This also relates to viscosity thus viscosity also changes.

5. Acknowledgements

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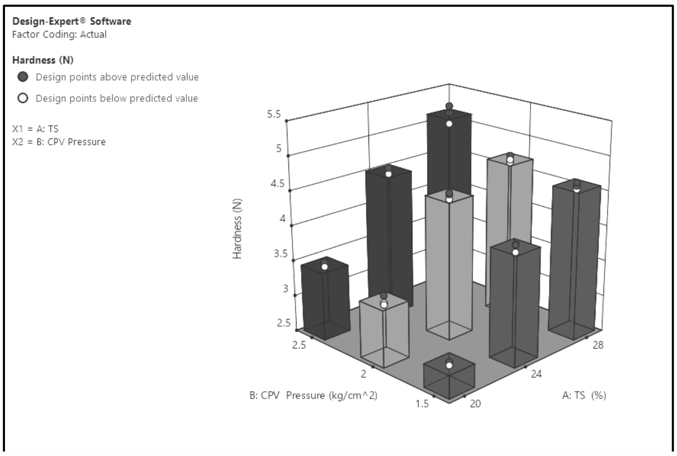
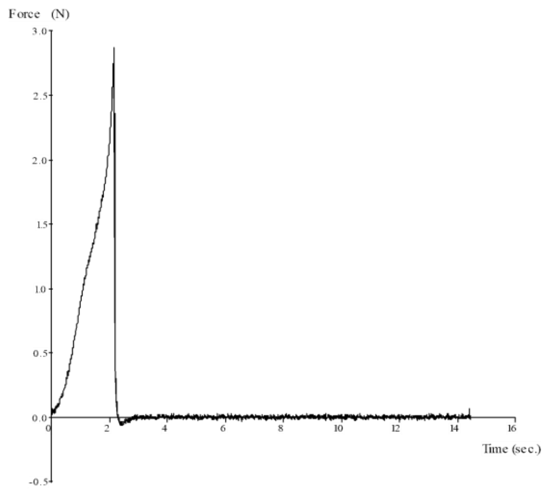
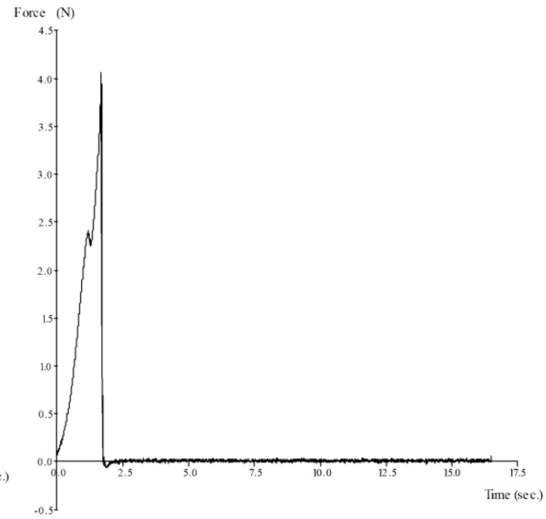


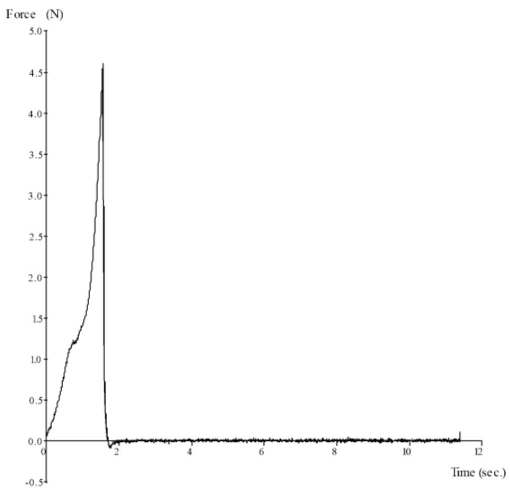
Fig 1: Effects of process parameters combinations on hardness of rice grain.



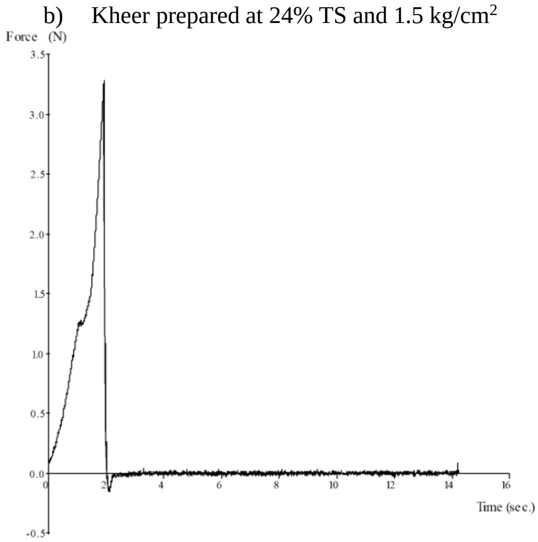
a) Kheer prepared at 20% TS and 1.5 kg/cm^2



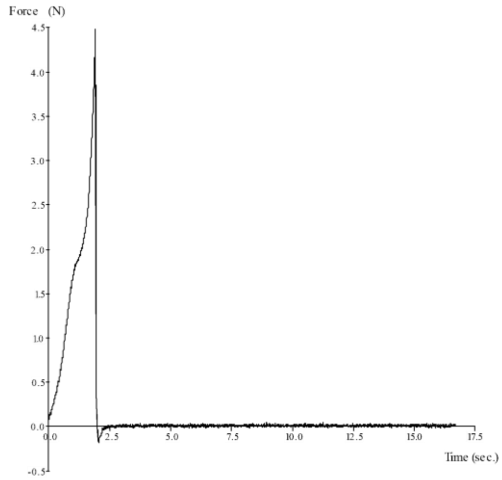
b) Kheer prepared at 24% TS and 1.5 kg/cm^2



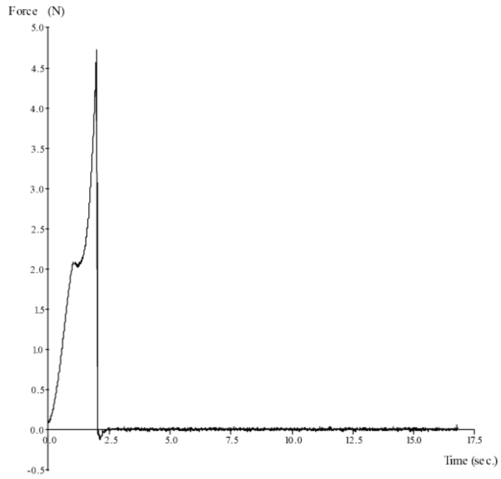
c) Kheer prepared at 28% TS and 1.5 kg/cm^2



d) Kheer prepared at 20% TS and 2.0 kg/cm^2

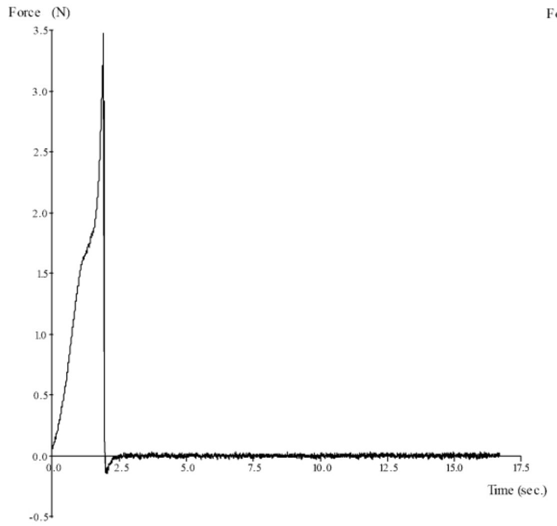


e) Kheer prepared at 24% TS and 2.0 kg/cm^2

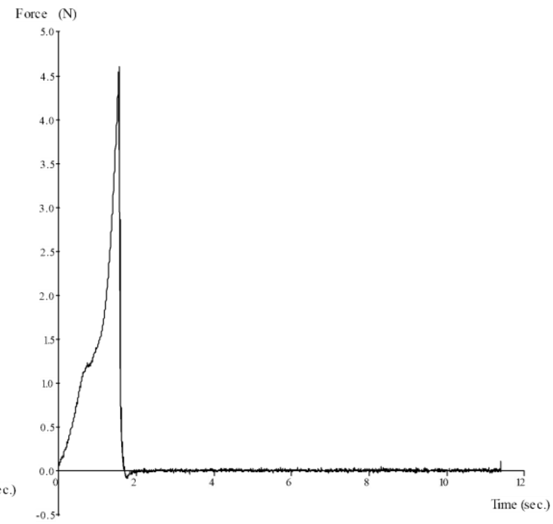


f) Kheer prepared at 28% TS and 2.0 kg/cm^2

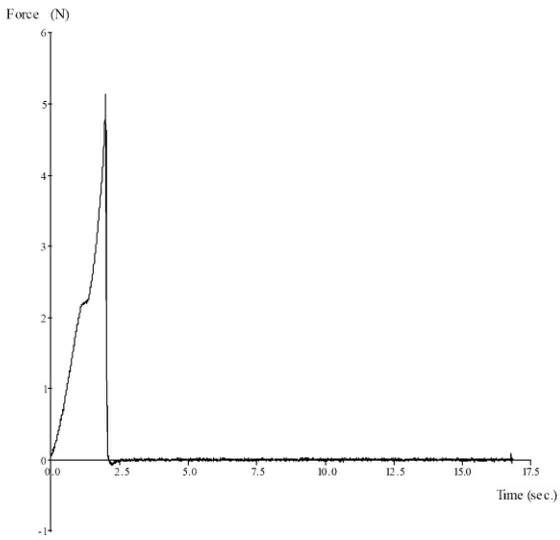
Fig 2: Texture profile analysis of rice grain (Set 1).



g) Kheer prepared at 20% TS and 2.5 kg/cm^2



h) Kheer prepared at 24% TS and 2.5 kg/cm^2



i) Kheer prepared at 28% TS and 2.5 kg/cm

Fig 3: Texture profile analysis of rice grain (Set 2).

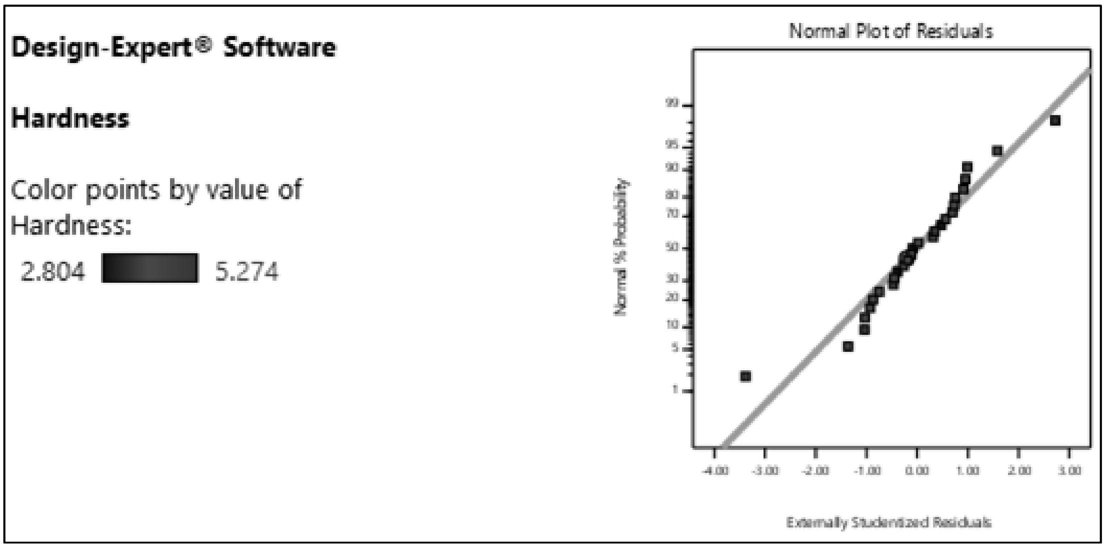


Fig 4: Probability plot showing how the data points lies around the line of best fit.

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