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Chemical changes of in-package microwave-treated dhap khoa during storage

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Abstract
In-package microwave-treated *dhap khoa* (a heat-desiccated milk product) was investigated to determine chemical changes during its storage at different temperatures. An optimized sample of *dhap khoa* packed in a polypropylene pack was stored at 10, 35 and 45 °C temperatures. The changes in Hydroxymethylfurfural (HMF), Thiobarbituric acid (TBA), and Free Fatty Acid (FFA) in the in-package microwave-treated *dhap khoa* were investigated during storage. In the fresh sample, the initial average value of HMF was 11.25 µmol/g. As the temperature increased to 10 °C, 35 °C, and 45 °C, the HMF values also increased to 13.51, 14.65, and 15.32 µmol/g, respectively. For TBA, the initial value at 532 nm was 0.004. With the rise in temperature to 10 °C, 35 °C, and 45 °C, the TBA values which increased to 0.012, 0.015, and 0.016, respectively. Regarding FFA, the value in the fresh sample was 9.5 µeq/g. As the temperature raised to 10 °C, 35 °C, and 45 °C, the FFA values further increased to 12.15, 12.66, and 13.67 µeq/g, respectively.

Keywords: Chemical changes, dhap khoa, FFA, HMF, microwave, TBA

1. Introduction
Around 50 percent of milk production in India is used to convert into various indigenous products, including various sweets found in different regions, each with unique names and flavours. The primary ingredients used for making these sweets are *khoa* and *chhana*. Various *khoa-based* sweets including *Peda*, Burfi, *Kalakand*, Milk cake, Gulab jamun etc. are prepared on various occasions in India. *Khoa* is considered as desiccated milk product and serves as the base material for most sweets prepared by halwais (sweet makers).
Khoa holds high commercial significance due to its use in various sweet preparations, which offer relatively high-profit margins. However, the production of *khoa*-based sweets is still largely conducted on a small scale, employing traditional *halwai* processes, and the marketing is typically limited to home-grown areas due to the relatively short shelf life of these sweets. The quality deterioration of food is influenced by various environmental factors such as light, temperature as well as packaging substantial. Unfortunately, these factors are often variable and have a significant impact on the shelf-life; and overall quality of food too (Burton, 1984; Kilcast and Subramaniam, 2000) [3, 10]. There are several physico-chemical and microbiological methods available for assessing the quality of *khoa*; however, most of these methods require a considerable amount of time, the use of chemicals, and laborious procedures (Byeon *et al*., 2009) [4].
A thorough examination of the changes that occur during the storage of *dhap khoa* facilitates the acquisition of kinetic information about the reaction rate constant. This, in turn, empowers the dairy industry to regulate and optimize storage conditions, leading to improvement in the retention of quality attributes in the product before it reaches to consumers. The careful selection of appropriate packaging and storage conditions plays a crucial role in achieving this goal. Considering the above facts, the present investigation was undertaken to observe various chemical changes in microwave-treated *dhap khoa*.

2. Materials and Methods
2.1 Materials
Fresh buffalo milk was received from Experimental Dairy, ICAR-NDRI, Karnal. Stainless steel cylindrical moulds (2.1 × 3 cm; Dia × height) were used for moulding the *dhap khoa* into cylindrical shapes. Moulds give mass of (11 g). Polypropylene microwavable safe packaging materials were procured from M/s Krishna Plastic and Packaging Material, New Delhi, India.

A convection microwave oven (make - IFB; model- 30 FRC2; power supply – 230 V~50 Hz; rated microwave output – 900 W; Operation frequency – 2450 MHz; Oven capacity – 30 Litres and cooking uniformity -turntable system) was used for in-package microwave treatment.

2.2 Preparation of *dhap khoa* sample

Dhap khoa was prepared as per the method given by Aneja *et al*., 2002 [1]. Freshly prepared *dhap khoa* was moulded with the help of stainless steel (SS) cylindrical mould giving mass of 11 g. It was then packed in a polypropylene pack (410 µm) under atmospheric conditions and subjected to in-package microwave treatment (360W microwave power for 20s residence time).

2.3 Storage temperatures and sampling times

The in-package microwave-treated *dhap khoa* was carefully packed in polypropylene packaging and stored at 03 different temperatures: 10 °C, 35 °C, and 45 °C. Sampling was conducted at regular intervals of 3 days for the 10 °C samples, while daily testing was performed for the samples kept at 35 °C and 45 °C.

2.4 Chemical analysis

The development of hydroxy methyl furfural (HMF), thiobarbituric acid (TBA) value and free fatty acid (FFA) was estimated during the storage period. The HMF and TBA values were measured using the method suggested by Keeney and Bassette (1959) [8] and Strange *et al*. (1977) [14] respectively. The analysis for FFA of *dhap khoa* was estimated using the method given by Deeth (1975) [7].

3. Results and Discussion

3.1 Changes in Hydroxyl-Methyl-Furfural (HMF) Content in-package microwave-treated *dhap khoa* during Storage

The impact of storage period and different temperature on HMF values in *dhap khoa* is depicted in Fig. (1a) and (1b).

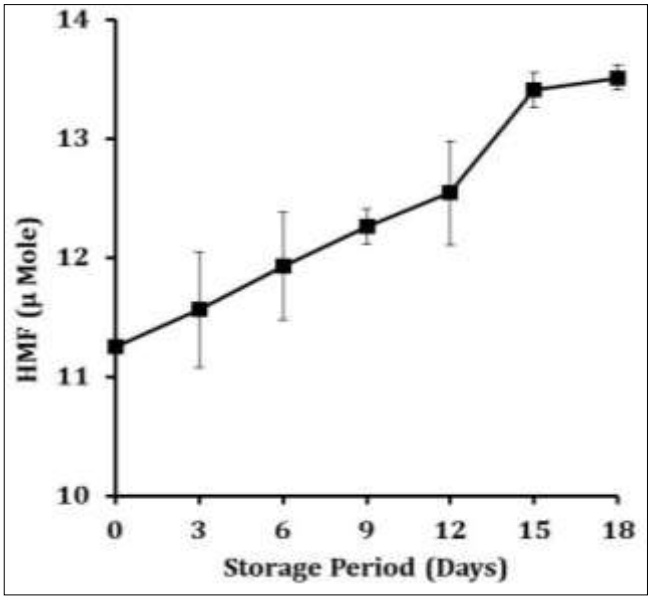

Fig 1a: Effect of storage temperature (10 °C) on HMF content of the *dhap khoa*

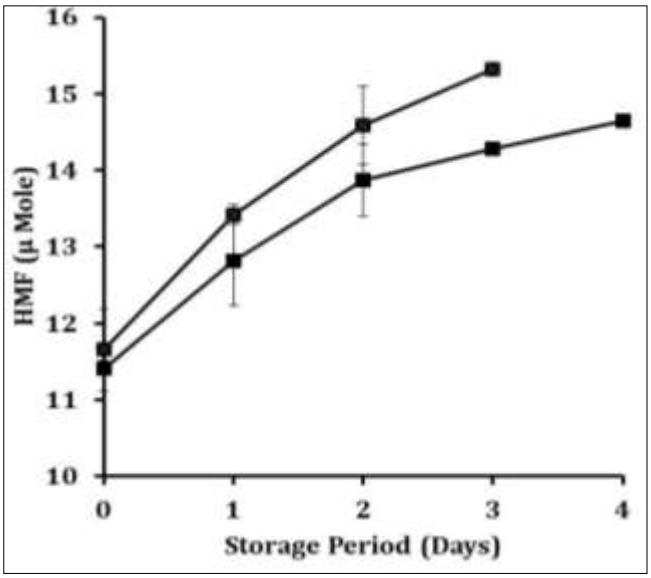

Fig 1b: Effect of storage temperature (35 °C and 45 °C) on HMF content of the *dhap khoa*

In the in-package microwave-treated *dhap khoa*, the initial average value of HMF was 11.25 µmol/g. This value increased to 13.51 µmol/g, 14.65 µmol/g, and 15.32 µmol/g at storage temperatures of 10 °C, 35 °C, and 45 °C, respectively. It was observed that the formation of HMF was comparatively lower in the samples stored at 10 °C compared to those stored at 35 °C and 45 °C. Typically, non-enzymatic browning processes, such as Maillard reactions, occur at a slower rate in dry systems and lower temperatures, but they become more predominant at temperatures above 35 °C (Labuza, 1984) [11]. As the storage temperature increased, there was a significant rise in the HMF content, which is consistent with findings in other studies. Similar observations were reported in pearl millet-based kheer mix (Bunkar *et al*., 2012) [2] and instant multi-grain *Dalia* mix (Singh *et al*., 2013) [13]. According to Caric (1984) [5], the levels of HMF (hydroxymethylfurfural) in dairy products experience a notable rise from 5.68 µmol/g to 28.43 µmol/g after 240 days of storage at room temperature. The formation of HMF in milk occurs during heat treatment and acidic conditions, primarily through Maillard reactions.

3.2 Changes in thiobarbituric acid value of in-package microwave-treated *dhap khoa*

The Thio Barbituric Acid Reactive Substances (TBARS) test is commonly employed. Throughout milk processing and storage, various chemical and physical transformations occur, including autoxidation and the generation of trans fatty acids, which contribute to the aldehydes, ketones, and lactones. These alterations can lead to a decline in the overall sensory attributes of the product (Seema, 2002) [12].

In the study of optimized *dhap khoa* as a baby food formulation, the increment in TBA value (measured at 532 nm) during storage is depicted in Fig. (2a & 2b). The TBA value in *dhap khoa* rose from an initial value of 0.004 to 0.012, 0.015, and 0.016 at 532 nm when stored at 10 °C, 35 °C, and 45 °C, respectively. Comparable increment in TBA value in instant wheat porridge (*dalia*) stored in different packaging materials and conditions were reported by Bunkar *et al*. (2012) [2] and Khan *et al*. (2012) [9].

The present study confirms the similar observations found in the previously mentioned research works, indicating the importance of monitoring TBA values to assess lipid oxidation and the quality changes during the storage of food products.

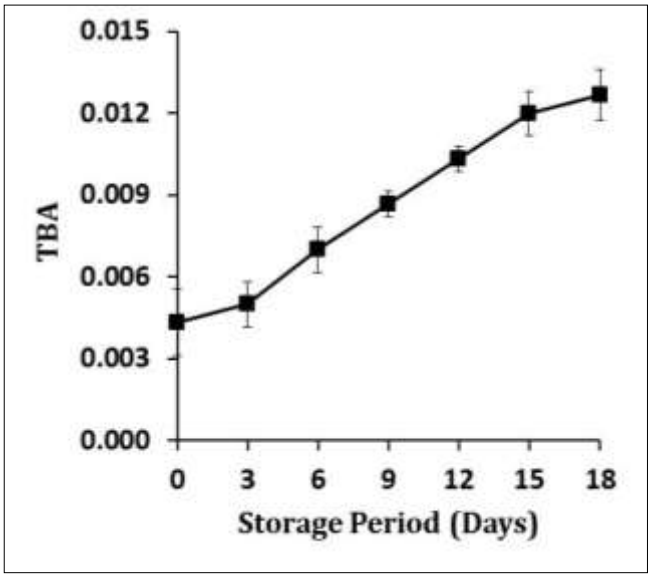

Fig 2a: Effect of storage temperature (10 °C) on TBA value of the *dhap khoa*

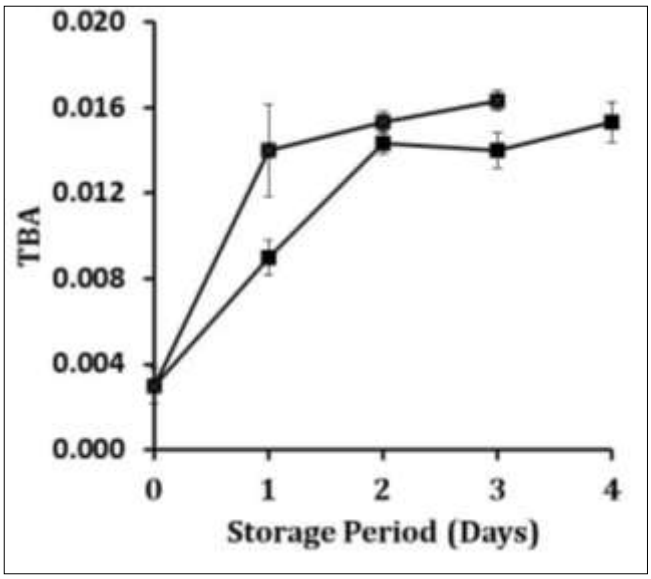

Fig 2b: Effect of storage temperature (35 °C and 45 °C) on TBA value of the *dhap khoa*

3.3 Changes occurred in FFA of in-package microwave-treated *dhap khoa*

Hydrolytic rancidity, which occurs due to enzymatic action like lipases generating free fatty acids, serves as marker of lipid oxidative degradation in various milk products (Clayton *et al*., 1972) [6].

The impact of storage on the FFA values of in-package microwave-treated *dhap khoa* is illustrated in Fig. (3a). The initial FFA value of 9.5 µeq/g in the fresh sample increased to 12.15 µeq/g, 12.66 µeq/g, and 13.67 µeq/g at 10 °C, 35 °C, and 45 °C, respectively, after 18 days of storage. Similar findings were also reported by Khan *et al*. (2012) [9].

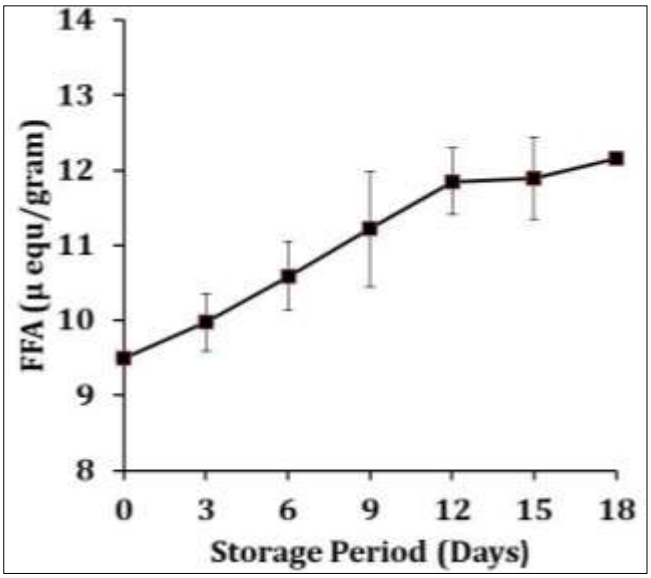

Fig 3a: Effect of storage temperature (10 °C) on FFA value of the *dhap khoa*

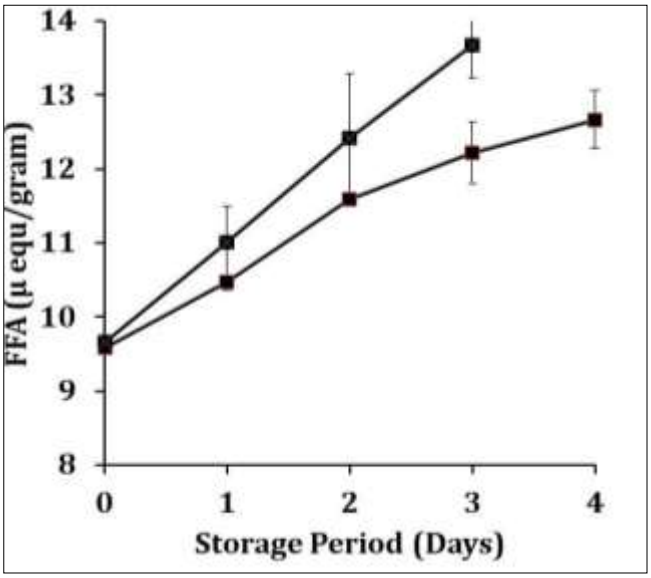

Fig 3b: Effect of storage temperature (35 °C and 45 °C) on FFA value of the *dhap khoa*

4. Conclusion

From the present investigation, it was found that in the in-package microwave-treated *dhap khoa*, the initial average of HMF was 11.25 µmol/g. As the temperature elevated, the HMF content also rose to 13.51 µmol/g, 14.65 µmol/g, and 15.32 µmol/g at 10 °C, 35 °C, and 45 °C, respectively. Additionally, the TBA measured at 532 nm, augmented from 0.004 to 0.012, 0.015, and 0.016 at 10 °C, 35 °C, and 45 °C, respectively. Furthermore, the FFA in the fresh sample, initially at 9.5 µeq/g, further increased to 12.15 µeq/g, 12.66 µeq/g, and 13.67 µeq/g at 10 °C, 35 °C, and 45 °C, respectively.

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