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Effect of hypobaric frying and impregnation on moisture and fat content of Gulabjamun balls

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Abstract
The current study was carried out to analyze the changes in moisture and fat content in the Gulabjamun balls during sub-baric frying and vacuum impregnation. The moisture content during frying of Gulabjamun decreased linearly with increasing frying temperature and time. It was found that moisture content was decreased from the initial value of 60.91% to 17.66, 15.71 and 12.74% (d.b.) at 110, 115 and 120 ºC, respectively. The fat content of Gulabjamun during sub-baric frying varied directly with increase in the frying time and inversely with increase in the frying temperature. During soaking the moisture content decreased with increase in the sugar concentration and increase in soaking time. The fat loss was higher when soaked in higher sugar concentration i.e. at 60ºBrix and increased with increase in soaking time across all syrup concentration evaluated. The fat values decreased from 25% to 11.25, 10, and 9.75% when soaked in 40, 50 and 60ºBrix syrup.

Keywords: Gulabjamun, sub-baric, vacuum and impregnation

Introduction

Gulabjamun is a fried and soaked dairy product which is widely popular all over India. The manufacture of Gulabjamun is largely contributed by halwais who adopt small scale batch method and hence there will be variations in the sensory quality of Gulabjamun. The product is characterized with brown colour, smooth and spherical shape, soft and slightly spongy body that is free from lumps, uniform granular texture and a pleasant cooked flavour (Kant and Broadwayb, 2017) [5]. The product should be fully succulent with sugar syrup with optimum sweetness.

Vacuum or sub-baric processing is a novel technique which is carried out at pressures well below atmospheric level. Literature reported that sub-baric frying offers a substitute way to fry fruit and vegetables to yield fried products of enhanced quality attributes. Most of the benefits of sub-baric frying are attributed to the low temperatures used and the minimal exposure to oxygen, which reduces the adverse effects on the oil quality, preserves the natural colour and flavour and nutritional value of the fried product (Yamsaengsung *et al*. 2011) [9]

Vacuum impregnation is rapid soaking method where a solution containing specific composition is introduced into the porous matrices of product by induced differences in pressure. The process facilitates large volumes of intercellular spaces in tissues of fruit and vegetables to be filled with the desired solution, thus altering physico-chemical properties and sensory attributes of products. Radziejewska-Kubdzela *et al*., (2014) [8] reported that this method may be used to lower the pH and water activity of a product, concurrently resulting in a change in its thermal properties along with improved texture, colour, taste and aroma. Several reports have cited the advantages of this process over conventional soaking in candying operations and rehydration of dried fruits and vegetables; including, savings in processing time, improved absorption capacity of the product, energy savings due to processing at ambient temperature etc. (Luciana *et al*., 2005) [6].

Materials and Methods

Preparation of dough

Dough was prepared by blending a mixture in the proportion of *khoa* (100g) and maida (30 g), kneaded in an orbital mixer (Make: M/s Lalith Industries, Bangalore, India) for 5 min. Representative samples were drawn and its moisture content was determined the using gravimetric method.

The required amount of water to correct the moisture content of khoa to 65% (d.b) was figured and potable water of that volume was added to the dough during the kneading process for uniform and homogenous distribution in the dough.

Sub-baric frying of Gulabjamun

The Gulabjamun balls prepared from the kneaded dough were processed in a sub-baric thermal processor (SBTP). The Gulabjamun balls were loaded into the trays and loading basket was lowered in to the heated oil bath by running the automated hoist system of the unit. For the experiments three levels of frying temperature were selected based on preliminary studies i.e., 110, 115 and 120 ºC (400 mm Hg) and the balls fried at the chosen temperature up to a duration of 5min and samples were drawn every 30 s for necessary analysis. After the lapse of the frying time, the trays were hoisted above the oil bath and suspended in full vacuum of 680mmHg for 10 min. Thereafter, the vacuum of the unit was broken, the hatch door of the unit was opened and the trays were retrieved to collect the fried Gulabjamun balls.

Vacuum Impregnation of Gulabjamun

The fried balls were loaded to perforated trays and the tray was introduced in the soaking unit of the SBTP containing bath of sugar syrup of desired strength in the tank at the bottom of the unit. The tray was held suspended in the headspace and a vacuum of 680mmHg was created. After a lapse of 5 min, the tray was instantaneously lowered into the syrup bath by activating the automatic hoist system. Once the tray was immersed in the bath, the vacuum was immediately released and the balls were held immersed in the bath at 30 °C for a period of 5 min. The tray was then lifted and removed from the SBTP to withdraw the soaked product for further analysis. Based on preliminary studies, three levels of soaking syrup concentration, *viz*., 40, 50 and 60 °C in combination with three levels of soaking time, i.e. 2, 4 and 6 min were selected and withdrawn every 60 s for mapping of its moisture and fat content.

Determination of moisture content

The whole Gulabjamun was ground using pestle and mortar. From the ground mass, about 5 g of the sample was taken and weighed accurately. The moisture content of the Gulabjamun was determined using oven drying method (Gravimetric method).

Estimation of fat content

About 1 g of the representative ground sample was taken in 100 ml beaker. The fat content was determined using the Mojonnier fat extraction apparatus explained in BIS (1981) [2]. The samples were digested using 10 mL of concentrated hydrochloric acid and were then added with 10 mL of ethyl alcohol. Fat was extracted with 25 mL each of diethyl ether and petroleum ether. The extraction was repeated 3 times and the superficial layer was decanted to a beaker of predetermined weight. The solvents were evaporated completely in a water bath. The residue obtained was dried in hot air oven at 100±2 °C for 1 h.

Results and Discussions

Moisture loss during sub-baric frying of Gulabjamun

The variation of moisture content with time for the 3 temperatures considered in this study is presented in Fig. 1. The moisture content during frying of Gulabjamun decreased linearly with increasing frying temperature and time. It was found that moisture content was decreased from the initial value of 60.91% to 17.66, 15.71 and 12.74% (d.b.) at 110, 115 and 120 ºC, respectively. At the same time interval, moisture content was lower at higher frying temperature attributed to the faster moisture evaporation at higher temperature gradients between the product and frying oil. This trend is in agreement with the results of Franklin *et al*., (2013) [3] and Neethu *et al*., (2014) [7].

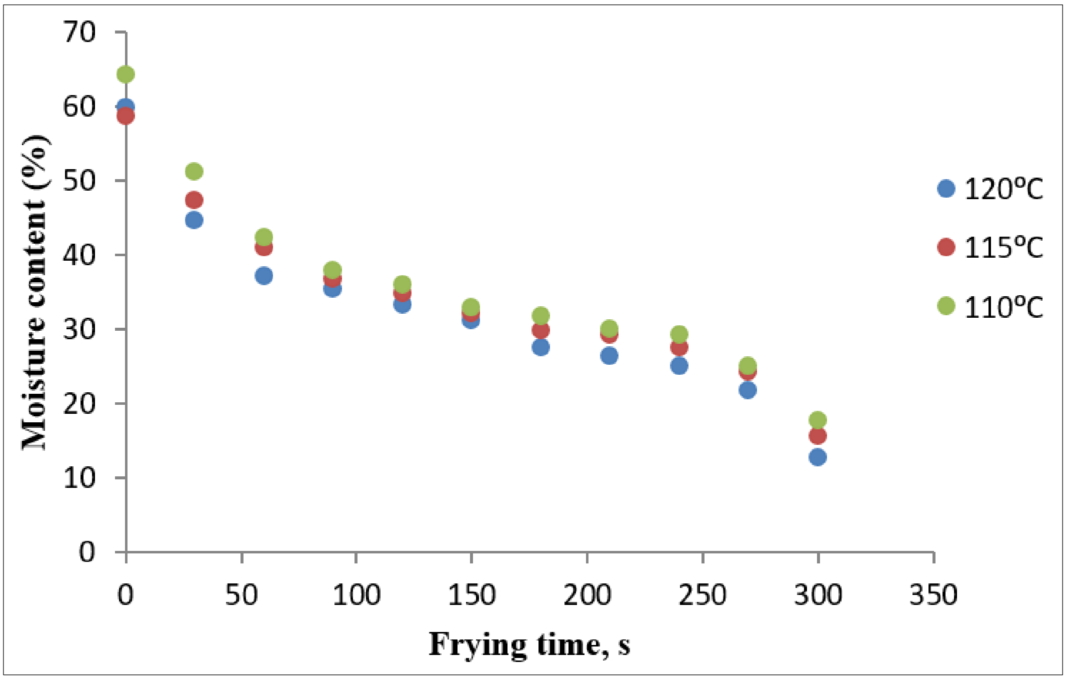

Fig 1: Moisture loss during sub-baric frying of Gulabjamun

Table 1: ANOVA of moisture content in Gulabjamun during Sub-baric frying

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Frying temperature	894.404	2	447.202	198.720	.000
Frying time	10380.539	16	648.784	288.296	.000
Frying temperature **x** Frying time	167.443	32	5.233	2.325	.003
Error	114.771	51	2.250		
Total	271076.614	102			
Corrected total	11557.157	101			

The statistical significance of the influence of the processing conditions on the moisture content of the product during frying is presented in Table 1 and both the factors, namely, frying temperature and time were determined to significantly influence the moisture content of the product.

Fat uptake during sub-baric frying of Gulabjamun

The fat content of the fried samples withdrawn at 30 s intervals were estimated using the Mojonnier method and the data for the 3 temperatures considered in this study is presented in Fig. 2.

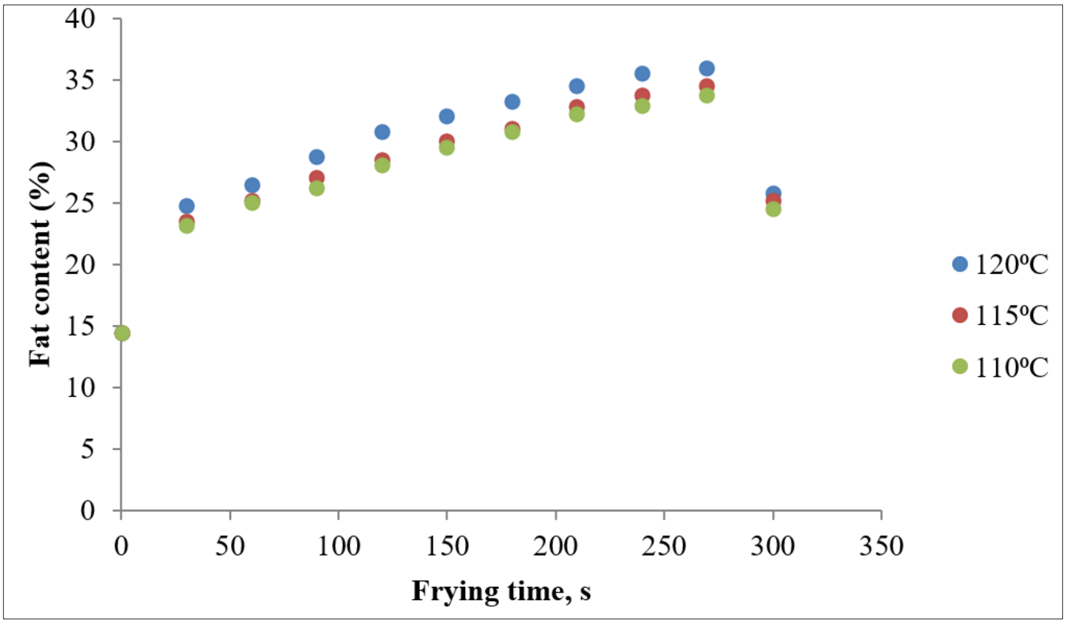

Fig 2: Fat uptake during sub-baric frying of Gulabjamun

The fat content of Gulabjamun during sub-baric frying varied directly with increase in the frying time and inversely with increase in the frying temperature (Fig. 2). The fat content increased from 14.5 to 24.5, 25.25 and 25.75% at 120, 115 and 110 ºC, respectively. It is evident from Fig. that the fat uptake was rapid in the initial stages of frying, replacing the evaporated moisture; the rate of fat uptake tended to taper off as the frying time approached 5 min. Similar trends for fat uptake during frying has also observed in potato chips, beef meat balls, tortilla chips and donuts (Gamble *et al*., 1987) [4].

The data for fat uptake during sub-baric frying was analysed using ANOVA and the results are summarised in Table 2. It can be seen that the fat content of the product was significantly influenced by the frying time but the frying temperature did not have a significant effect. This is in contrast to results presented in Neethu *et al*., (2014) [7] and Franklin *et al*., (2013) [3] and could be due to the narrow range of temperatures used in this study.

Table 2: ANOVA of fat content in Gulabjamun during Sub-baric frying

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Frying temperature	47.114	2	23.572	5.059	.012
Frying time	2118.030	10	211.803	45.460	.000
Frying temperature ***** Frying time	8.106	20	0.405	0.087	1.000
Error	153.750	33	4.659		
Total	54520.00	66			
Corrected total	2327.030	65			

Moisture gain during sub-baric soaking of Gulabjamun

The temporal variation of moisture content during sub-baric soaking of Gulabjamun is presented in Fig. 3 and it was observed to decrease with increase in the sugar concentration and increase in soaking time. The moisture content in the product increased from 18.61 to 55.54, 41.91 and 36.63 at 40, 50, and 60ºBrix. The moisture content in the lower sugar concentration was higher probably due to lesser penetration of sugar and faster influx of the syrup at lower viscosities (Barat *et al*., 2002) [1]. The statistical significance of the process parameters for the moisture gain during sub-baric soaking of the product was evaluated in terms of the two way ANOVA and the results are summarised in Table 3. Both major factors and their interaction were found to exert significant influence on the moisture content in Gulabjamun during Sub-baric soaking

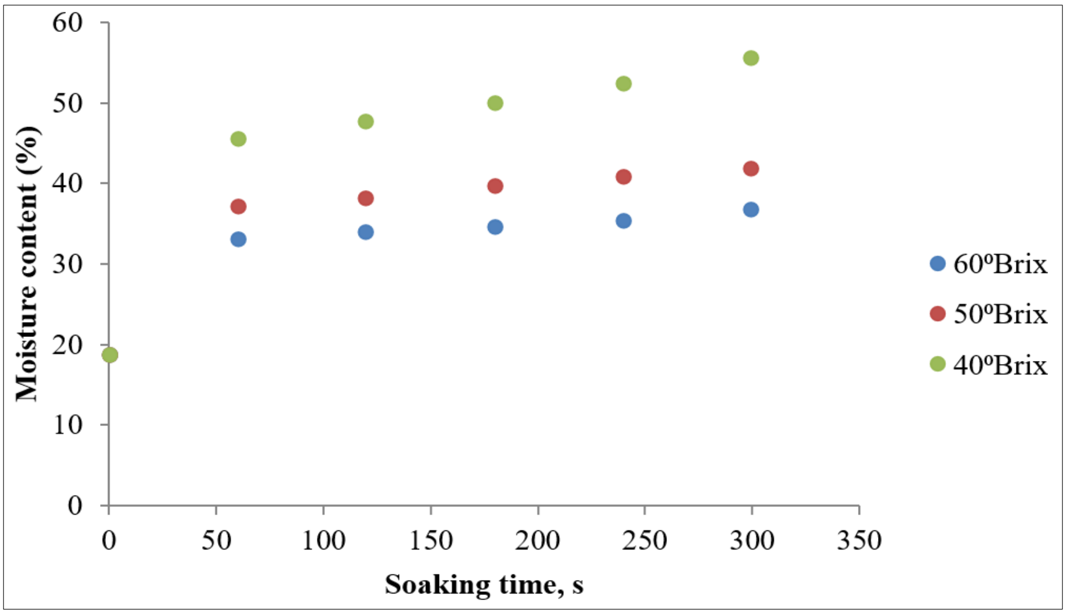

Fig 3: Moisture gain during sub-baric soaking of Gulabjamun

Table 3: ANOVA of moisture content in Gulabjamun during Sub-baric soaking

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Soaking concentration	1567.098	2	783.549	940.259	.000
Soaking time	4136.517	5	827.303	992.764	.000
Soaking concentration * Soaking time	356.599	10	35.660	42.792	.000
Error	30.00	36	0.833		
Total	82778.732	54			
Corrected total	6090.215	53			

Fat loss during sub-baric soaking of Gulabjamun

The fat content of the fried Gulabjamun balls sub-barically soaked in the three syrup concentrations and drawn at 60 s intervals were estimated using Mojonnier method and the result is plotted as Fig. 4. It can be seen that the fat loss was higher when soaked in higher sugar concentration i.e. at 60ºBrix and increased with increase in soaking time across all syrup concentration evaluated. The fat values decreased from 25% to 11.25, 10, and 9.75% when soaked in 40, 50 and 60ºBrix syrup.

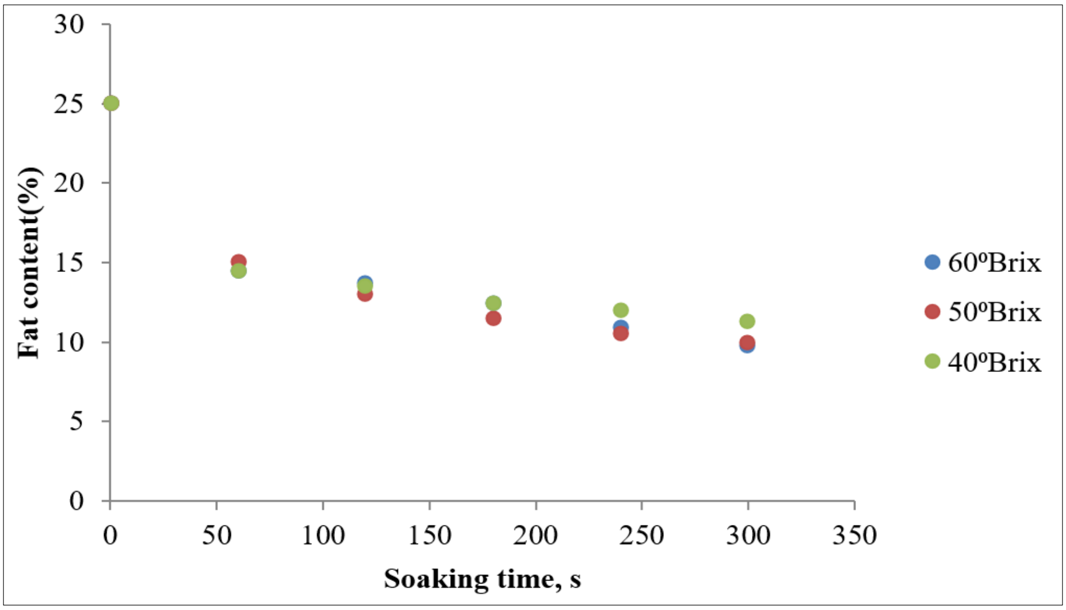

Fig 4: Fat loss during sub-baric soaking of Gulabjamun

Table 4: ANOVA of fat content in Gulabjamun during Sub-baric soaking

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Soaking concentration	5.128	2	2.564	4.749	.022
Soaking time	849.134	5	169.827	314.534	.000
Soaking concentration * Soaking time	9.580	10	0.958	1.774	.139
Error	9.719	18	0.540		
Total	8580.938	36			
Corrected total	873.561	35			

The data was also analysed using two way ANOVA to understand the statistical significance of the process parameters and the results are presented in Table 4. It can be deduced that soaking time had a more profound influence on fat loss during sub-baric soaking of Gulabjamun; the interactive effect of the parameters was not significant.

Conclusion
The moisture content of Gulabjamun balls were decreased during sub-baric frying and increased during vacuum impregnation and vice-versa for the fat content. The data generated in this study would be useful for future engineering applications such as simulation, design improvements for better process control and enhanced energy efficiency.

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