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Sustainability Spotlight Statement

The incorporation of eutecto-oleogels as fat replacers in wheat dough and cookies offers a sustainable alternative to conventional solid fats. By forming oleogels from healthier unsaturated oils, it reduces dependency on saturated fats and associated risks to health. Eutecto-oleogels serve the dual purposes of improving textural homogeneity and moisture retention in food products while maintaining dough handling qualities. This innovation not only supports health-driven reformulation but also promotes the use of plant-based lipids, contributing to more sustainable and nutritionally responsible bakery products.

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Impact of eutecto-oleogel on functional, textural and rheological attribute of wheat flour cookies as fat replacer

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Abstract

The study aimed to understand the effect of eutecto-oleogel on wheat dough and cookie quality. Oleogel was prepared using rice bran oil, beeswax, starch, and natural deep eutectic solvents (NADES) constituting malic acid and glucose. The cookies' quality was evaluated based on their physicochemical, functional, rheological, and textural properties at oleogel concentrations, 20 % to 100 % of total fat. The cookies' quality such as dimension, color, water solubility, and textural properties varied significantly (p>0.05). The basic chemical composition, textural properties, and physical attributes of the cookies were compared and provided a better acceptability. The sensory analysis using 9-point hedonic scale was accomplished and the sample with 60% oleogel showed the highest overall acceptability. Furthermore, the changes in cookie texture and stability were monitored during 35-days storage at room temperature (25°C)in 75 and 94% RH. It was found that in almost all properties, the oleogel cookies resembled control cookies. This manifested a new approach to replace the solid fat from the confectionary.

Keywords: Eutecto-oleogel; Physical attributes; Texture; Sensory acceptability; Shelf life

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1. Introduction

Solid or semi-solid fats are widely used in the bakery industry because of their significant impact on the flavour, texture, and oxidative stability of food products[1]. Consequently, techniques like interesterification and hydrogenation were employed to convert liquid oils into solid or semi-solid fats[2, 3]. Saturated and trans fatty acid concentrations in the oil rise after hydrogenation and their detrimental effects on human health are extensively demonstrated [4]. According to the U.S FDA consumption of saturated fat results in increased blood levels of total cholesterol and low-density lipoprotein (LDL or “bad”) cholesterol which in turn increase the risk of cardiovascular disease. Cardiovascular disease is the leading cause of death in both men and women in the India and a similar trend is observed all over the world. As per WHO recommendations, the daily consumption of saturated fatty acids must not exceed 10%.United States officially banned the use of trans fat by removing the partially hydrogenated oils from the GRAS (Generally Recognized As Safe) list in June 2018, making their addition to foods illegal, Canada’s nationwide ban effective in September 2018, the State of California’s banned its use in 2010 and the New York City’s banned in 2008.An alternative method needs to be developed to transform liquid vegetable oils into solid or semi-solid fats with a low content of trans and saturated fatty acids.

Oleogelation is an innovative alternative technology that has attracted significant attention in recent years[5]. The process of trapping oil in a 3D network using a low concentration of oleogelator chemicals and without changing the fatty acid composition of oil unlike hydrogenation is known as oleogelation, also known as organogelation[6]. Numerous biopolymers, including proteins, polysaccharides, and combinations are employed for the hydrogel phase. Thus oleogels structured solid-like materials in which a high amount of liquid oil entrapped

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within a self-standing, anhydrous, thermos reversible, three dimensional network of gellator molecules [7]. Thus, the potential uses of this technique received a great popularity and are being used for various bakery products[8, 9]. However, applications of eutecto oleogels in bakery products are limited.

Cookies are highly consumed ready-to-eat and convenient baked flour confectionary with global estimated market of USD 12.14 billion in 2024 and are expected to grow to USD 18.77 billion by 2029. Solid fat in cookies serves the primary function of providing lubrication of gluten particles to prevent large chain formation, and plasticity of dough and to tenderize the finished product. Growing awareness and health concerns have led consumers to seek better alternatives in food consumption, driving the expansion of the healthy cookies market[10]. Various studies have been conducted to discover the potential of oleogel to replace solid fat in cookies. Previous research revealed the effect of oleogels made with Hazelnut oil, sunflower oil, virgin olive oil, flaxseed oil, and soybean oil structured using different types of waxes (e.g. carnauba wax, rice bran wax, sunflower wax, beeswax, candelilla wax) in cookie manufacturing[11, 12]. However, eutecto oleogels with rice bran oil were not used in cookies.

Therefore, the study was aimed to develop cookies with eutecto-oleogel. It was assumed that eutecto-oleogel would be an alternative for the fats and would not vary the cookies property as compared to the conventional fat. Thus, the objectives of the study were a) development of cookies with eutecto-oleogel, b) the physiochemical and flow properties of the dough and comparison with conventional cookies and c) effect of oleogel on the sensory properties and shelf-life of the cookies.

2. Materials and Methods

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2.1. Raw Materials and Chemicals

Rice bran oil was purchased from Tezpur, Assam, India. The Malic acid and glucose were procured by SRL (Maharashtra, India). Beeswax of *Apis mellifera* was purchased from HiMedia Laboratories Pvt. Ltd. (India). It is a lipid that contains hydrocarbons, esters and free acids. Joymoti rice starch was collected from the Lab of Food Engineering and Technology Department, Tezpur University. Refined wheat flour, sugar, baking powder, salt and butter were procured from the local market of Tezpur. All other reagents and chemicals used for analysis were of analytical grade.

2.2. Preparation of oleogel

Oleogel were prepared using rice bran oil, beeswax, starch and natural deep eutectic solvents (NADES) constituting malic acid and glucose in the ratio of 1:1[13]. For oleogel preparation firstly, NADES and starch were mixed to attain uniform mixture using magnetic stirrer. Subsequently rice bran oil was added into the mixture while being mixed and heated simultaneously to 80 °C for 30minusing temperature controlled magnetic stirrer. Once the mixture reaches the temperature, the beeswax was incorporated into the mixture while mixing continuously. Further to facilitate the gel formation, this homogeneous mixture was cooled to atmospheric temperature followed by resting for 24 h at 20 °C. The sample containing 9 % beeswax, 1 % starch and 15 % NADES in reference to 100 % rice bran oil (RBO) have been selected for this study based on the observations made in our previous research work.

2.3. Preparation of cookies

Six different cookies samples were prepared with varying the proportion of oleogel and butter as Table 1. Six different samples having varying ratio of butter and oleogel (100:0, 80:20, 60:40, 40:60, 20:80,0:100) were prepared keeping overall shortening to 30 g. The samples were

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prepared according to method given by Hamdani, Wani, and Bhat[14]. For preparing dough 100 g refined wheat flour were thoroughly mixed with 30 g of shortening for 3 min. Then, 0.5 g baking powder was added and mixed properly. Finely powdered 45 g white sugar were added to the mixture and further mixed for 1 min. After that 0.5 g salt dissolved in 2 ml of water for proper mixing of salt was introduced into the sample and mixed thoroughly for 1 min. After thorough mixing of all these ingredients 15 ml water were added and dough were prepared by kneading it for 3 min. The prepared dough was allowed to rest for 5 min. Then, the dough was sheeted to a thickness of 5±0.5 mm using flat board and rolling pin and then cut into a circular shape using die of 50mmdiameter. Fifteen cookies were placed on aluminum tray in one go and baked at 180 °C in the baking oven. The baked cookies were cooled to room temperature (25±1°C) and were stored in airtight container at room temperature until further analysis.

2.4.Weight Loss and Dimension of cookies

Weight loss of cookies during baking was measured for 15 randomly selected cookies sample. For this, the difference between the final weight of baked and cooled cookies and the initial weight of each cookie sample were measured. The diameter and thickness of the 15 selected cookies were measured according to Emin Yılmaz and Mustafa Öğütcü[11] using digital vernier calipers respectively. The spread ratio were calculated as described by [15] and expressed by the ratio of the average diameter and average thickness of the cookies.

2.5.Color analysis

The color of 15 selected cookies from each sample type was quantified through CIELAB parameters (L, a, and b) by using Hunter Lab Ultra Scan VIS Spectrophotometer (Hunter Lab Inc., Reston, VA, USA). The data were analyzed using easy-match QC software.

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2.6.Textural Properties of cookies

The hardness and fracturability of the 15 selected cookies were analyzed by texture analyser (Model # TAHD Plus; Make # Stable Microsystems, UK) equipped with a 30 kg load cell and warner bratzler rectangular notch blade probe. The analysis were performed with the pre-test speed of 3mm/sec, test speed of 1mm/s, post-test speed of 5mm/s with triggering force of 0.100 N. The resultant force-time curve were evaluated for maximum peak force giving hardness and first significant peak force for fracturability of the cookies sample**.**

2.7.Functional properties of cookies

The functional properties of the prepared cookies samples such as Water Absorption Index (WAI) and Water Solubility Index (WSI) were analyzed according to Hashem et al [16]. The cookies samples were finely grounded and for water absorption index 4±0.5g of powdered cookies sample were transferred to weighed centrifuge tube followed by addition of 30 ml of distilled water. The slurry were stirred using glass rod to break any possible lump present and further centrifuged at 3000 rpm for 10 min at ambient temperature (25°C) in centrifuge (Model # 5430R; Make # Eppendorf Germany). The supernatant and sediment were separated appropriately and the weight of the sediment gel was recorded and the water absorption index was calculated as per stated equation (1).

$$WAI\ (\%) = \frac{weight of sediment}{weight of dry sample} \times 100 \qquad (1)$$

For determination of water solubility index 2.5 g of finely grounded cookies sample were added in 25 ml distilled water and stirred for 30 min using magnetic stirrer. The slurry were transferred into tarred centrifuge tube and were made up to 32.5 g and further centrifuged at 3000rpm for 10 min at ambient temperature (25 °C) using centrifuge (Model # 5430R; Make # Eppendorf

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Germany). The supernatant were carefully transferred to previously weigh evaporating aluminum dish and the solid dissolve in supernatant were recovered by evaporating the liquid part. The water solubility index were calculated by the stated equation (2)

$$WSI\ (\%) = \frac{weight\ of\ solid\ recovered\ from\ supernatant}{weight\ of\ dry\ sample} \times 100 \quad (2)$$

2.8.Rheology of dough

Rheological analysis of dough were carried out according to Das et al [17] with slight modification. Frequency sweep analysis was performed by rheometer (Model #Physical MCR 72; Make #Antron Paar, Graz, Austria) using 25 mm flat probes to determine the strength of the dough. Analysis was performed at ambient temperature by applying a constant strain of 1% and varying frequency from 1 to 100 rad/s. The storage and loss modules of samples were determined.

2.9. Compositional analysis

The moisture content of the cookies samples were analyzed according to AOAC method 925.10 using a hot air oven. The Ash content of the cookies was determined by the AOCS Ba 5a-49 technique. Soxhlet apparatus were used to measure total fat content of the cookies using AOAC 920.39 method. Crude protein content was measured using Kjeldahl method as per method stated by AOAC, 2005, method 979.09[18]. All the readings were taken in triplicates.

2.10. Sensory analysis

The sensory evaluation of the cookies sample were performed according to Owheruo et al [19] with slight modification. Semi-trained panelists of 15 members belonging to age group of 18 to 35 years and different eating habits voluntarily participated for the sensory evaluation. The panelists were staff and students of the Department of Food Engineering and Technology, Tezpur University. The samples were evaluated for color, texture, taste, flavour and overall acceptability

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based on 9 points hedonic scale (1 - dislike extremely;2- dislike very much; 3 - dislike moderately; 4 - dislike slightly; 5- neither dislike nor like; 6- like slightly;7- like moderately; 8 - like very much; 9 - extremely like).

2.11. Storage study

The cookies sample was standardized based on sensory analysis. The standardized sample O_{60} and O_0 (control) were prepared and stored in zippered polypropylene bags at two different relative humidity 75 % and 94 % attained using sodium chloride and potassium nitrate salt at 25°C. Every 7th day the samples were withdrawn and analyzed for weight gain, moisture content, texture and peroxide value. Peroxide value was measured according to method given by AOAC [18].

2.12. Statistical analysis

To identify the significant difference between the means, the data was analyzed using Duncan's multiplerange test (DMRT) using SPSS Statistics 17.0 software (IBM, Chicago, USA). The significant difference at p≤0.05 was shown by the different letters in superscript in the same column.

3. Results and discussion

3.1.Physical properties of cookies

The physical properties of the cookies were analyzed in term of weight loss, diameter, and thickness and spread ratio, summarized in Table 2. The weight loss percentage of the cookies was decreased with increase in oleogel concentration. The cookies sample O_0 had highest weight loss during baking of 16.11 % whereas the cookies O_{100} have lowest weight loss of 11.38 %. The weight loss of cookies during baking generally refers to the reduction in mass due to the

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evaporation of moisture and the release of gases. Oleogels are structured oils, there is less moisture to evaporate during baking, which minimizes weight loss [20]. Additionally, oleogel networks were proposed as a way to prevent moisture migration during baking. In addition, the natural deep eutectic solvent inhibited moisture from evaporation during baking. Similar kind of observation was reported by Savi [21] with citric acid and sucrose natural deep eutectic solvents. The diameter of cookies slightly increases with increase in oleogel concentration whereas thickness of the cookies shown slight decrease with increasing concentration of oleogel. The observed result was similar to Kim and Oh [22]. Kim and Oh[22] compared the cookies made with shortening and Tenebrio Molitor larvae oil based oleogel using oleogelators (candelilla wax, carnauba wax, and beeswax). They found that cookies made with beeswax oleogel had highest diameter and lowest thickness. Similar kind of result were reported by Öğütcü, Arifoğlu, and Yılmaz[23] during the studied with sunflower wax and beeswax/hazelnut oil-oleogelin cookies. The melted oleogel could result in more free oil within the dough during baking, which encourages spreading as the structure softens. This free oil reduces the internal rigidity in the dough, enabling it to spread wider, thus increasing the cookie diameter and reduces thickness. It was obvious that as diameter increase and thickness reduces, there spreadability increases which was agreed from our present finding. The present findings are in the agreement with previously conducted study [22].

3.2.Color attribute of cookies

The color of 15randomly selected samples were analyzed in terms of L, a, and b values (Table 2). The brightness of the cookies sample without oleogel (O_0) was found to be the highest. The results reveal that the cookies having increased concentration of oleogel were darker compared to cookies made with butter. Oleogel consisted of beeswax, starch, and NADES, which markedly

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reduced the L value of the cookies. The sampleO_{100}showed the highest a(redness) and b (yellowness) values. It was suggested that malic acid and glucose could participate in non-enzymatic browning reactions at high temperatures, contributing to the formation of brown pigments (melanoidins)[24]. This result is consistent with that obtained by Li [15]investigated the effect ofoleogel prepared by five different gellator (hydroxypropylmethylcellulose, mono-acylglycerol, sodium stearyl lactate, rice bran wax, and beeswax) oleogel replacement on cookie attributes.

3.3.Textural Properties of cookies

The texture analysis of the cookies revealed that the fracturability and hardness of the cookies significantly ($p<0.05$) decreased with increasing concentration of oleogel (Table 3). This result could be due to the high fat content of the oleogel. The eutecto-oleogel exhibits low internal resistance to flow because its microstructure consists of a weak, partially crystalline network formed by beeswax and starch that entraps oil and NADES components. Oils possess a loosely packed molecular structure with weak intermolecular interactions, which results in low internal resistance to flow. This structural arrangement allows oil molecules to move and slide past one another with minimal energy input. When applied between solid surfaces, the mobile oil molecules spread uniformly and form a continuous, thin lubricating layer. This layer separates the surfaces and prevents direct solid–solid contact, thereby reducing friction and stress concentration. Consequently, less force is required to initiate crack formation and propagation, leading to lower fracture energy. Similarly, reduced resistance to surface deformation manifests as lower measured hardness. Similar result has been found by Jadhav et al [25] for cookies with oleogel. Cookies with medium chain triglycerides oleogel showed less hardness compared to butter cookies [25]. A similar observation was reported by Emin Yılmaz and Mustafa Öğütcü [11]

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when cookies made by incorporating commercial bakery shortening and beeswax-based oleogel were investigated.

3.4.Functional properties of cookies

Water Absorption Index (WAI) and Water Solubility Index (WSI) of the cookies were evaluated to determine the functional properties of the cookies (Table 3). Water absorption index were found to decrease with increase in oleogel concentration from 183.35 to 142.06 %. The oleogel are consisted of high amount of rice bran oil, thus cookies showed hydrophobic in nature [24]. When eutecto-oleogel is incorporated into cookie dough, its structured oil and NADES network surrounds part of the water present in the system. This reduces the amount of free water available to interact with hydrophilic components such as starch and proteins. Since these components rely on direct contact with water to swell, hydrate, and bind moisture, the presence of oleogel decreases their ability to absorb water effectively. As a result, the overall water absorption capacity of the dough decreases. This limited water availability can influence dough handling, texture, and spread during baking, as less water is taken up by the flour components. Similar kind of observation was reported by Oh and Lee [26] for the noodles with soybean oil-candelilla wax oleogel. The water solubility index of the cookies was not affected significantly in presence of oleogels. Oleogels do not affect the water solubility of cookies because they are hydrophobic and interact with the fat phase rather than the water phase. Mert and Demirkesen[27] reported similar observation for cookies with candelilla wax containing oleogels.

3.5.Rheological properties of dough

Rheological analysis was conducted to investigate the effect of the incorporation of oleogel on the flow properties of dough developed for cookies. Fig.1(a) and Fig.1(b) present the storage modulus (G’) and loss modulus (G’’) of the samples. The storage modulus of the dough sample

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shows an increasing trend with an increase in oleogel concentration. This result signifies that the rigidity of the dough increased with an increase in oleogel concentration.The oleogelacts as additional reinforcement to the dough's internal network, leading to increased resistance to deformation. The dough becomes more elastic and able to recover its shape after stress is applied, hence a higher G' was observed. On the other hand, increasing the concentrations of starch and beeswax within the eutecto-oleogel system enhances the overall structural firmness because both components contribute to a more solid, interconnected network. Beeswax forms crystalline structures that remain solid at room temperature, acting as a rigid scaffold. Starch granules, when present in higher amounts, add additional bulk and structural support. Together, they limit molecular mobility within the matrix, making the eutecto-oleogel more stable and less deformable. This strengthened network increases rigidity, resulting in a firmer texture and a more robust structure that better resists mechanical stress or deformation during handling or processing. Loss modulus also shows a similar trend with storage modulus for dough.

3.6.Proximate composition of cookies

The moisture content of the cookies increased with increasing concentration of oleogel in the sample (Table 4). The present result for weight loss during baking justifies the observed moisture content of the cookies. The cookies having a higher concentration of oleogel, loose less moisture during baking. Oleogels are structured oil systems where the liquid oil is entrapped in a three-dimensional network formed by starch, beeswax, and NADES. This structure could influence the interaction and evaporation of water from cookies during baking. The fat percentage also showed an increasing trend with the increase in oleogel concentration of the cookies. Oleogels are typically structured oils, where liquid oil is trapped within a gel matrix, while butter contains both fat and water. Butter usually has around 80% fat and about 15-20% water, along with other

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milk solids. On the other hand, oleogels consist almost entirely of fat. Thereby, this difference in composition means that when the same quantity of oleogel and butter is used in a recipe, the oleogel inherently provides more fat content because it lacks the water and solids present in butter. A similar result has been found by Yilmaz et al [28] who investigated the cookies made using hazelnut oil-based oleogel structured using sunflower wax/beeswax and commercial bakery shortening. It was reported that the fat percentage of the cookies with beeswax-based oleogel was highest. The Ash content of the cookie sample decreases with an increase in oleogel content. Similar observations have been made by Yilmaz et al [28]. The protein content of various samples doesn't show a significant difference (Table 5).

3.7.Sensory analysis

The sensory evaluation of various cookies samples was performed according to 9-point hedonic scale to determine the consumer acceptance of the cookies (Table 6). The sample with varying amount of oleogel composition showed comparable result with control O_0 sample. The overall acceptability of the cookies sample O_{60} was found to be highest (7.73) followed by O_{20} and O_0. The color, taste and flavour of the O_{60} cookie sample showed comparatively highest acceptance by the panel among all the samples. For the presence of oleogel, cookies create a smooth and creamy mouth feel that enhances the perception of richness, which is often a desirable sensory trait. As oleogels are made from liquid oils, the release of flavors tends to be more efficient, which improves the overall sensory experience of cookies.

3.8.Shelf life of cookies

For self-life analysis, the cookie sample O_{60} were selected as it showed the highest favourable sensory attribute. A short time (35 days) storage study was carried out at two different relative humidity of 75% and 94%. At every 7^{th}days, the textural attributes i.e., fracturability and

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hardness, moisture content and peroxide value of O_{60} were measured and compared with control sample O_0.

3.8.1. Moisture content

Moisture content of all the cookies samples were analyzed at the interval of 7 days till 35 days. The moisture content of oleogel sample was found to be higher than O_0 sample in both the relative humidity condition. Fig. 2 (a) shows the increase of moisture with storage days. The moisture content of cookies sample increased gradually at 75% RH whereas the samples stored at 94% RH picked up moisture very rapidly in comparison. O_{60} sample stored at 94% RH were found to have highest moisture content at the end of 35 days. It was suggested that for the presence of oleogels in the cookies the porosity in the network increases, which allows more space in the structure thus higher amount of moisture to penetrate into the cookie.

3.8.2. Fracturability and hardness

Fracturability and hardness of the entire cookies sample shown increasing trend with increasing days of storage. Moisture changes, starch retrogradation, fat crystallization, and other structural changes are the main causes of increased fracturability and hardness of cookies during storage [29]. The control sample O_0 stored at 75% RH (75C) showed least fracturability at the end of 35 days whereas theO_{60} sample stored at 94% RH (94O) showed highest fracturability. The cookies with butter might undergo lower rate of moisture loss as well as starch retrogradation as compared to cookies with oleogel.

3.8.3. Peroxide value

The peroxide value of the cookies was measured to estimate the oxidative stability of the products. Results revealed that the O_0cookies have similar peroxide value at both the storage condition of 75 % RH and 94 % RH. Whereas the O_{60} sample showed that the storage condition

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elevated the peroxide valueof the cookies made using oleogel. At the storage condition of 75 % RH sample O_{60} showed similar peroxide value as butter but at 94% RH the peroxide value increased drastically. Oleogels are made from rice bran oils which are rich in unsaturated fatty acids, particularly polyunsaturated and monounsaturated fats. These unsaturated fats are more prone to oxidation compared to the saturated fats present in butter, thus cookies with oleogels provided higher peroxide value during storage.

4. Conclusion

The study successfully demonstrated that oleogel could replace the solid fat from the confectionary. The rice bran oil was used as a solid fat replacer, an oleogel was successfully prepared using rice bran oil and natural wax, and oleogelation effectively improved the oxidative stability during storage time under the accelerated condition. As a result of applying the oleogel to cookies instead of shortening, the hardness of oleogel cookies with beeswax was lower than that of shortening cookies and tended to become softer. In addition, the oleogel cookie with beeswax did not show significant differences in the spread factor and texture properties compared to the cookie with shortening, indicating the possibility of serving as an alternative to shortening.

The study demonstrated that eutecto-oleogel is a promising fat replacer in cookies, as formulations up to 60% oleogel delivered desirable physicochemical, textural, and sensory qualities. Oleogel cookies closely matched control samples and maintained stability during storage, indicating their potential for developing healthier bakery products without compromising quality.

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Declarations

Ethical approval

Not applicable

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' contributions

Deepali Sinha: Methodology, Formal analysis, Data curation.

Poonam Mishra: Conceptualization, Resources, Review & editing the final draft, Supervision, Funding acquisition.

Amit Baran Das: Resources, Review & editing the final draft, Supervision, Funding acquisition.

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Availability of data and materials

The data will be available based on request.

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Figure caption

Fig. 1. Rheological behaviour of dough samples, (a) storage modulus and (b) loss modulus

Fig. 2. Effect of storage on (a) moisture content; (b) fracturability; (c) hardness and (d) peroxide values of cookies samples during storage (O_{60}/75: sample containing 60 % oleogel and stored at 75% RH; O_0/75: sample containing 100% butter and stored at 75% RH; O_{60}/94: sample containing 60% oleogel and stored at 94% RH; O_0/94: sample containing 100% butter and stored at 94% RH)

Table caption

Table 1 Composition of the cookies and coding

Table 2 Effect of incorporation of oleogel on color attributes of developed cookies

Table 3 Textural and functional attributes of cookies

Table 4 Proximate composition of cookies

Table 5 Sensory attributes of developed cookies

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Table 1 Composition of the cookies and coding

Samples	**Composition (g)**						
	Flour	**Butter**	**Oleogel**	**Sugar**	**Baking Powder**	**Salt**	**Water (ml)**
O_0	100	30	0	45	0.5	0.5	17
O_{20}	100	24	6	45	0.5	0.5	17
O_{40}	100	18	12	45	0.5	0.5	17
O_{60}	100	12	18	45	0.5	0.5	17
O_{80}	100	6	24	45	0.5	0.5	17
O_{100}	100	0	30	45	0.5	0.5	17

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Table 2 Effect of incorporation of oleogel on color attributes of developed cookies

Sample	Weight loss (%)	Diameter (mm)	Thickness (mm)	Spread Ratio	L	a	b
O_{0}	16.11±0.92^{d}	47.97±1.05^{a}	7.62±0.35^{b}	6.30±0.35^{a}	68.78±3.78^{b}	5.66±1.96^{a}	20.63±0.85^{a}
O_{20}	14.53±0.84^{c}	48.13±0.92^{a}	7.23±0.41^{a}	6.67±0.37^{ab}	66.81±4.04^{b}	6.71±1.94^{a}	20.86±0.59^{a}
O_{40}	12.94±0.62^{b}	48.20±0.72^{a}	7.18±0.51^{a}	6.74±0.53^{b}	68.78±2.98^{b}	5.82±1.43^{a}	20.17±0.59^{a}
O_{60}	12.73±0.8^{b}	48.42±1.01^{a}	7.14±0.56^{a}	6.81±0.50^{b}	57.45±4.79^{a}	10.36±0.92^{b}	22.57±1.45^{b}
O_{80}	11.83±0.70^{ab}	48.51±1.10^{a}	7.07±0.22^{a}	6.85±0.19^{b}	57.67±4.49^{a}	10.25±1.26^{b}	22.59±0.96^{b}
O_{100}	11.38±0.91^{a}	48.62±0.70^{a}	6.95±0.42^{a}	7.01±0.40^{b}	56.71±5.64^{a}	10.47±1.49^{b}	22.6±1.34^{b}

Means with different superscript in the same row indicate that there is significant difference between samples ($p \leq 0.05$) from Duncan's multiple range tests

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Table 3 Textural and functional attributes of cookies

Sample	Fracturability (N)	Hardness (N)	WAI (%)	WSI (%)
O_0	47.45±2.06^d	80.75±2.64^e	183.35±1.008^e	31.13±1.02^a
O_{20}	45.93±1.40^{cd}	76.66 ±2.67^d	167.97±3.56^d	31.06±0.54^a
O_{40}	43.85±1.36^{bcd}	71.46 ±2.20^c	152.32±3.33^c	29.83±0.59^a
O_{60}	42.93±3.97^{bc}	67.47±2.54^b	150.08±0.95^b	30.90±0.44^a
O_{80}	40.52±3.36^b	64.15±1.49^a	149.91±1.64^b	31.48±1.51^a
O_{100}	36.01±2.88^a	62.66±2.64^a	142.06 ±0.70^a	31.15 ±1.02^a

Means with different superscripts in the same row indicate that there is a significant difference between samples ($p \leq 0.05$) from Duncan's multiple range tests.

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Table 4 Proximate composition of cookies

Sample	Moisture (%)	Ash (%)	Fat (%)	Protein (%)
O_0	2.45±0.16^a	1.01±0.07^d	13.88±0.20^a	6.25±0.12^a
O_{20}	2.95±0.29^b	0.94±0.05^d	14.46±0.01^b	6.25±0.25^a
O_{40}	3.12±0.18^b	0.84±0.01^c	14.99±0.01^c	6.25±0.10^a
O_{60}	3.44±0.13^c	0.74±0.02^{bc}	15.59±0.12^d	6.24±0.02^a
O_{80}	3.62±0.04^{cd}	0.66±0.08^{ab}	16.24±0.13^e	6.24±0.14^a
O_{100}	3.86±0.10^d	0.59±0.01^a	16.79±0.14^f	6.24±0.01^a

Means with different superscript in the same row indicate that there is significant difference between samples ($p \leq 0.05$) from Duncan's multiple range tests.

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Table 5 Sensory attributes of developed cookies

Sample	Color	Texture		Taste	Flavour	Overall acceptability
		Fracturability	**Bite hardness**			
O_0	7.06±0.96^{a}	7.46±0.91^{a}	7.33±0.72^{a}	7.86±0.74^{ab}	7.66±0.61^{b}	7.47±0.83^{bc}
O_{20}	7.46±1.06^{a}	7.53±1.06^{a}	7.53±1.24^{a}	7.73±0.70^{ab}	7.6±0.82^{ab}	7.67±0.89^{bc}
O_{40}	7.46±0.83^{a}	7.53±0.99^{a}	7.33±0.97^{a}	7.40±0.91^{ab}	7.33±0.97^{ab}	7.33±0.97^{abc}
O_{60}	7.53±0.83^{a}	7.40±1.12^{a}	7.13±1.12^{a}	8.06±0.96^{b}	7.73±0.79^{b}	7.73±1.03^{c}
O_{80}	7.06±1.22^{a}	6.86±0.99^{a}	6.86±1.12^{a}	7.26±0.96^{a}	6.93±0.79^{a}	6.93±0.79^{ab}
O_{100}	6.73±1.03^{a}	6.73±1.03^{a}	6.73±1.38^{a}	7.13±1.12^{a}	7.07±1.16^{ab}	6.67±1.17^{a}

Means with different superscript in the same row indicate that there is significant difference between samples ($p \leq 0.05$) from Duncan's multiple range tests.

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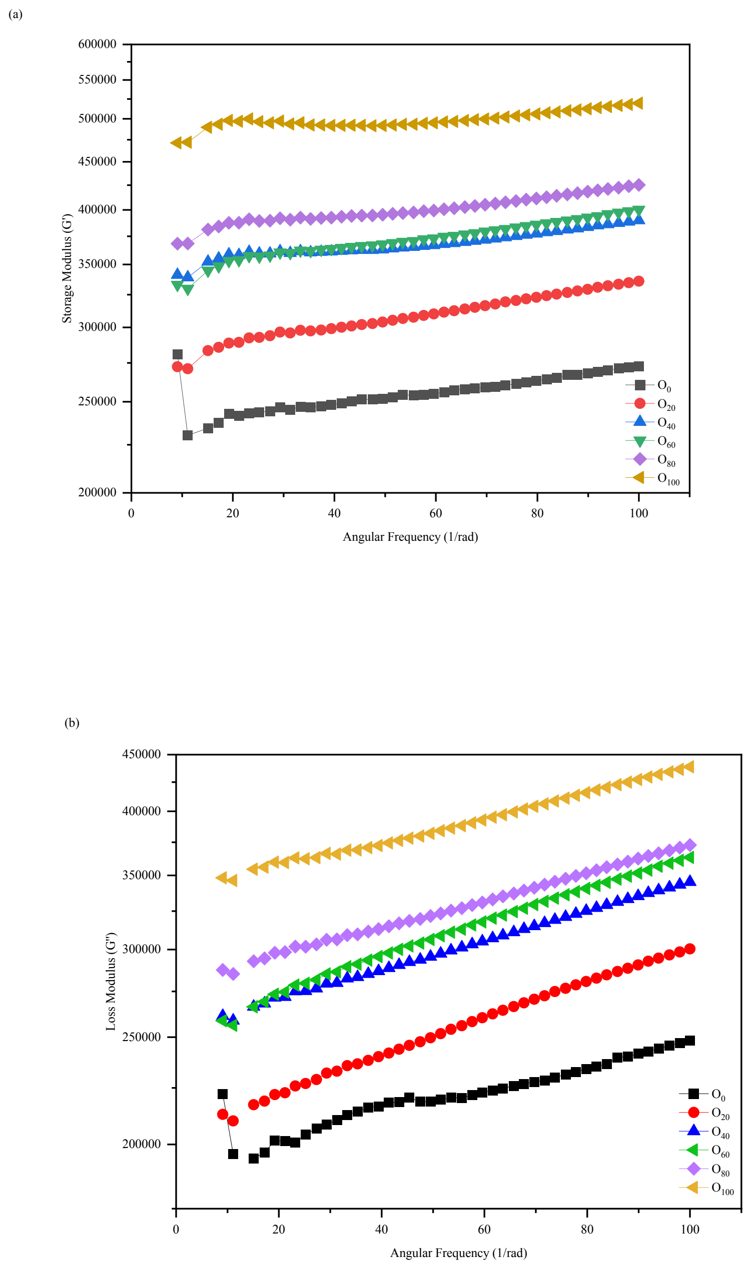

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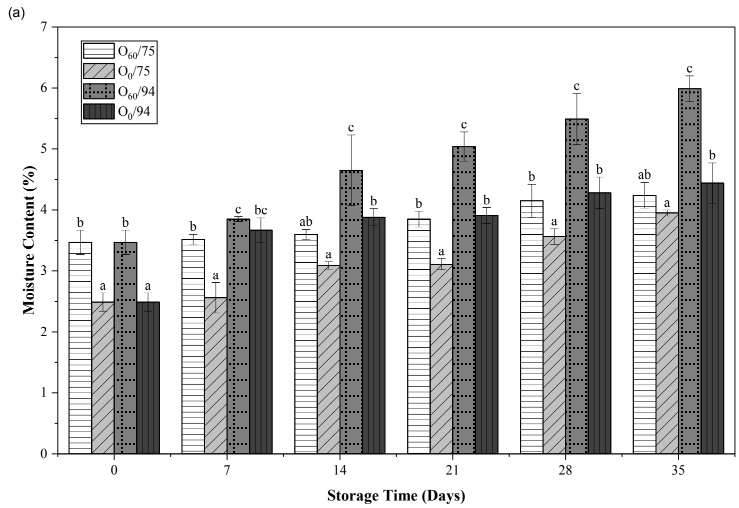

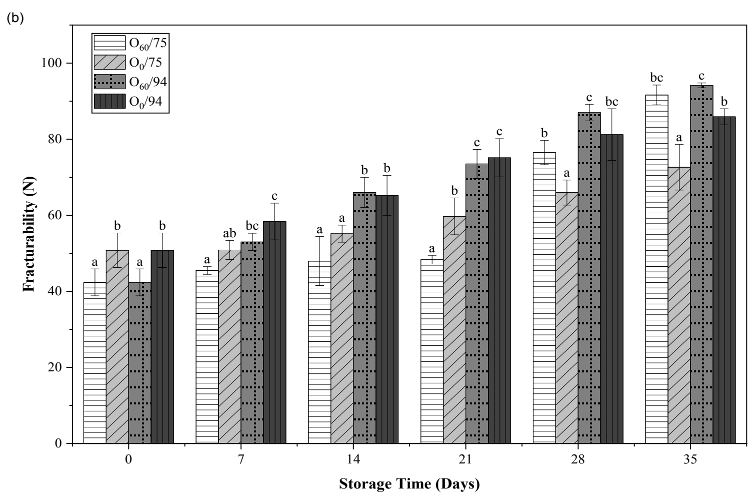

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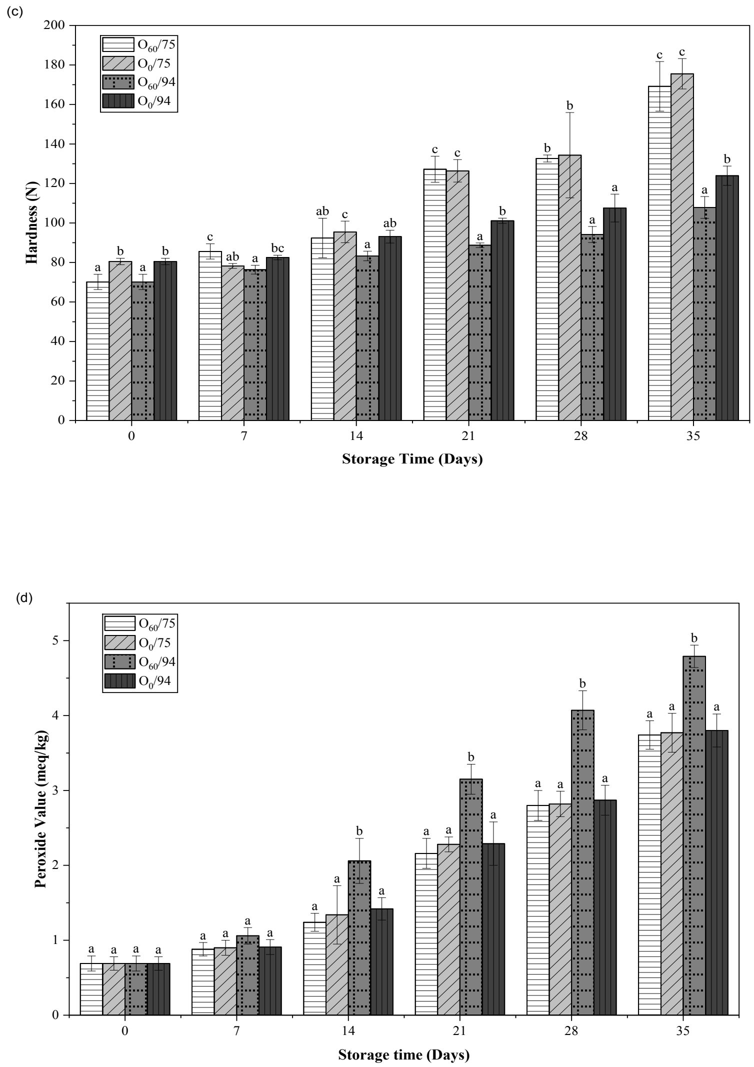

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The data will be available based on request.