



Shortening replacement by emulsion and foam template hydroxypropyl methylcellulose (HPMC)-based oleogels in puff pastry dough. Rheological and texture properties

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ABSTRACT

Shortening plays an essential function in the formulation of sweet laminated bakery products, but has a potential health risk due to their high percentage of saturated fatty acids. In this paper, the feasibility of hydroxypropyl methylcellulose (HPMC) oleogels prepared with emulsion template (ET) and foam template (FT) approaches as fat sources in a puff pastry dough was investigated. Spreadability and thermal properties of control shortening, 100% ET and FT oleogels and shortening/oleogel (50/50) blends were measured. The different systems were applied as the fat source in a puff pastry dough, and their effect on rheological and texture properties was investigated. Results showed that partial replacement of shortening with oleogels could significantly decrease the firmness values (from 115 to 26 N) ($P < 0.05$) and increased the spreadability of shortening. The methodology to prepare the oleogel (FT or ET) also significantly affected the texture parameters. FT blends had the highest spreadability with significantly lower firmness values and area under the curve. Thermal values showed that both oleogels could slightly increase the melting point of shortening from 47 to 50 °C. The replacement of shortening with oleogel decreases the viscoelasticity of puff pastry dough and increases its thermal stability but does not significantly change dough viscoelasticity in the shortening/oleogel mixture. These results indicated that both oleogels have promising potential to replace shortening in puff pastry dough formulations, but the ET oleogel showed a more similar behavior to the control shortening than the FT oleogel.

1. Introduction

Laminated bakery products are highly appreciated worldwide for their characteristic light and flaky texture (Selaković et al., 2021). Fat (shortening, margarine, butter) is wrapped around the basic dough (flour, salt, water) and then repeatedly rolled and folded to form a laminated dough comprised of alternating layers of dough and thin layers of fat. The fat is also called rolling fat because of its unique folding and rolling method of production, which requires excellent softness and plasticity to enable layering without breaking the dough layers, but not being too soft to leak out under pressure (Mattice and Marangoni, 2017). The layered structure enables each individual dough layer to be baked separately, and the water turns into steam during baking, causing the expansion of the dough layers to create visual layering and flaky texture characteristics (de la Horra et al., 2015; Gabriele et al., 2008; Šoronja-Simović et al., 2017). In the absence of shortening, the gluten and starch granules will stick together and make the dough stiff and

low-volume (Lim et al., 2017). In contrast, shortening envelops the gluten particles, which causes a discontinuity in the protein and starch structure and lubricates the gluten particles, forming a small and soft inflated product. Butter is commonly considered a favorable rolling fat, but the high cost and restricted plasticity range limit its large-scale production in laminated doughs (Mattice and Marangoni, 2017), so shortening is becoming the priority for preparing industrial laminated dough products. It provides not only functionality but also texture and lubrication. However, the problem currently confronted is the high amount of saturated fatty acids present in rolling fats (Lai and Lin, 2007; Silow et al., 2017). It is well-recognized that the excessive intake of saturated fatty acids can be harmful to health, increasing the risk of cardiovascular disease and leading to obesity and diabetes (DiNicolantonio et al., 2016; Hamley, 2017). Hence, there has been a tremendous effort in the search for alternative fat sources with healthy fat profiles without altering the typical food quality properties. Vegetable oils liquid at room temperature because of their low saturated fatty acid

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content, cannot be employed in the preparation of laminated doughs where high plasticity fats are required. Also, due to the high unsaturation, liquid vegetable oils are prone to oxidation, and their storage stability is significantly reduced.

Oleogels are an alternative to conventional solid fat. Oleogels are generated by wrapping liquid oil in a three-dimensional gel network using gelators and could have rheological, viscoelastic characteristics similar to those of solid fats. Typical food gelators include waxes, fatty acids, proteins or polysaccharides, as well as their complexes. The differences in gelling agent properties lead to various oleogel preparation methodologies. Hydrophobic gelators like waxes and fatty acids are mostly added directly to the oil phase, whereas hydrophilic gelators like polysaccharides need indirect methodologies, as they are not able to interact directly with the oil. The most common indirect methodologies for obtaining oleogels with hydrophilic polysaccharides are the emulsion-template and foam template approaches.

The application of oleogel as fat source in baked food is limited to specific foods, such as cookies (Li et al., 2021; Mert and Demirkesen, 2016b; Zhao et al., 2020), cakes (Aliasi Khiabani et al., 2020; Ashok and Patel, 2014; Oh et al., 2017), and muffins (Lim et al., 2017; Oh and Lee, 2018). Most of the attention was focused on the oleogels and the final product's sensory properties. However, there are no studies about the effect of oleogels on the dough physical properties before baking, which is highly correlated with the quality of the final product (Mironeasa and Mironeasa, 2019; Zhang et al., 2022). Knowledge about the structural effects induced by oleogel and by shortening/oleogel blends incorporated in the dough will be of great importance for the further development of oleogels in bakery products application.

Cellulose was recognized as a promising natural polysaccharide oleogelator with healthy food properties (Elleuch et al., 2011; Yang Jiang, 2018). Ethylcellulose can be directly soluble in the oil phase to form oleogels, but requires a high temperature above 140 °C (glass transition temperature). Moreover, its oleogel plasticity and oil adsorption ability is relatively weaker compared to conventional shortening. The cellulose ethers hydroxypropyl methylcellulose (HPMC) and methylcellulose (MC) have attracted enormous interest for their excellent surface activity and foaming structure that can effectively prepare stabilized oleogels with high oil retention capacity (Bascuas et al., 2020; Bascuas et al., 2020; Meng et al., 2018). Its amphiphilic properties come from the partial substitution of the hydroxyl group by hydroxypropyl and methoxyl groups. In puff pastry, Blake and Marangoni (2015) found that the consistency of the shortening must be like the dough to obtain a flaky pastry. HPMC emulsion template oleogels were successfully used as shortening replacer in a croissant formula; the croissant became chewier and more cohesive as the oleogel increased. A replacement level of 50% provided the most similar sensory perception (Espert et al., 2023).

The methodology to obtain MC and HPMC oleogels affected their physicochemical properties. The emulsion template oleogels showed lower values of the viscoelastic moduli and higher oil retention capacity than the foam template oleogels, although no significant differences were found in viscoelasticity (G''/G'), in both oleogels, a predominance of the elastic versus the viscous component was found. The obtaining method and the initial oil content had more effect on the oleogel structure than the type of cellulose (Wang et al., 2023).

This paper focuses in the comparison of HPMC oleogels obtaining methodology (emulsion and foam template approaches) in their application as shortening replacers in a puff pastry dough formula. Oleogels and oleogel/shortening (50/50) blends were characterized and applied as fat sources to prepare a puff pastry dough. Textural and rheological properties of the different doughs were compared. The different fat sources' physical properties were related to the corresponding doughs' physical properties. Results will provide useful information for further development and application of oleogels as total or partial shortening replacers in cereal baked food formulations.

2. Methods and materials

2.1. Materials

Hydroxypropyl methylcellulose (29% methoxyl, 6.8% hydroxypropyl) was supplied by The Dow Chemical Company (Bomlitz, Germany). Sunflower oil (oleic acid over 70%) was purchased from Deoleo S.A. (Córdoba, Spain). Shortening Hojaldambar (palm, sunflower, and soy oil with variable proportions; emulsifier (E471), flavorings and coloring (carotenes)) was obtained from Vandemoortele Europe NV (Gent, Belgium). Flour, sugar, milk, liquid egg and salt were bought from local Carrefour supermarket (Valencia, Spain).

2.2. Preparation of oleogels

- 1) **Emulsion-template approach (ET)**. The preparation method of ET oleogels with 96% (w/w) oil content was carried out as previously described by (Espert et al., 2020; Wang et al., 2023). In brief, 3 g HPMC powder was dissolved in 94 g sunflower oil, then 103 g drinking water at 10 °C was added to the oil, and the mixture was stirred at 200 rpm for 2 min using a Heidolph stirrer (RZR 1, Heidolph Instruments, Germany) to obtain an initial emulsion. The initial emulsion was further homogenized by a high-speed disperser (Ultraturrax T-18, IKA, Germany) at 16500 rpm for 1 min and the resultant milky white emulsion was dried in a 60 °C forced-air convection oven (Binder GmbH, Germany) for 24–48 h to reach a moisture content of less than 0.5% (w/w). Finally, the dried sample was crushed with a high-speed disperser (Moulinex, Groupe SEB (France)) to obtain the oleogel.
- 2) **Foam-template approach (FT)**. The FT oleogels were prepared according to the method of Oh and Lee (2018) with slight modifications. 4.5 g of HPMC powder was dissolved in 95.5 g of hot water (>85 °C), and subsequently 200 g of cool water (<10 °C) was slowly added. The entire dissolution process was carried out with a mixer (RZR 1, Heidolph Instruments, Germany) at 400 rpm for 10 min. The solution was homogenized at 16500 rpm for 2 min using a high-speed disperser (Ultraturrax T-18, IKA, Germany) and was lyophilized to remove water with a freeze-dryer (Lyobeta 6 PL, Telstar, Spain). The resulting foam was then minced with a kitchen grinder (Moulinex, Groupe SEB, France). Subsequently, 96 g sunflower oil was mixed thoroughly with 4 g of the chopped foam sample until a uniform oleogel was formed.

2.3. Preparation of oleogel/shortening blends

The shortening (62.5 g) was gently softened by heating in a 40 °C water bath for 10 min to form a semi-solid, and then an equivalent amount of oleogel was added and mixed thoroughly to form a 50/50 shortening/oleogel blend. Finally, the blend was placed in a square mold 15 cm × 10 cm before it solidified and stored in the fridge for subsequent testing and dough preparation. The same protocol was also applied to control shortening. 100% oleogel samples were directly placed into the mold.

2.4. Spreadability measurements

The spreadability of the oleogel and shortening/oleogel blends was determined by a texture analyzer TA.XT plus (Stable Micro Systems Ltd. Surrey, UK) equipped with a TTC Spreadability Rig. The test was performed in compression mode with a penetration depth of 25 mm, a test speed of 1 mm/s and a post-test speed of 10.0 mm/s. Prior to measurement, the sample was placed into the inner cavity, gently flattened with a spatula to avoid air incorporation, and then stored at 4 °C for 24 h. Measurements were carried out by pressing the sample with a conical probe and returning it to the initial position. Force versus distance data was recorded, and then the maximum force, the area under the curve

(AUC) and stickiness were calculated.

2.5. Thermal properties

Thermal analysis was carried out with a Q2000 Differential Scanning Calorimeter (DSC) (TA Instruments, New Castle, USA) according to a previous methodology (Espert et al., 2021) with slight modifications. 11–15 mg of sample was weighed into an aluminum pan and then sealed with a press. An empty pan was used as control. Samples (10–15 mg) were hermetically sealed in an aluminum pan and heated from 20 to 130 °C at the rate of 5 °C/min under a nitrogen atmosphere. All results were recorded and analyzed by the Universal Analysis 2000 software (TA Instruments, New Castle, DE).

2.6. Dough making procedure

The dough formula was composed of: 250 g flour, 35 g sugar, 1 g salt, 15 g yeast, 60 g egg, 125 g milk, and 125 g fat. Fats employed were: shortening (control), a blend made with shortening and oleogel (50/50), and 100% oleogel. Both ET and FT oleogels were tested. Sugar, salt, eggs and 25 g of the corresponding fat were added to a food processor (Kenwood titanium major kitchen machine, KM020, UK) for mixing 10 s at speed 6 (Kenwood titanium major kitchen machine, KM020, UK). Then, the flour and the yeast previously diluted with the milk were added and mixed at speed 6 for 20 s. The dough was then kneaded by hand for 10–15 min until a homogeneous texture was obtained. The dough was covered with plastic film and placed in the refrigerator at 4 °C to ferment for 8 h. Subsequently, the dough was rolled into a 40 cm × 15 cm flat rectangle. A square of fat/blends (100 g) was placed in the center of the dough square and the sides of the dough were folded towards the middle of the fat square so as to envelop it into one entity completely. After that, the dough with the fat was rolled into a rectangle, folded into three layers and placed in the refrigerator for 20 min. This final step was repeated three times to obtain the final dough.

2.7. Dough rheological properties

The rheological properties of the dough were measured by an AR-G2 rheometer (TA Instruments, Montreal, QC, Canada) equipped with a 40 mm diameter hatch parallel plate geometry and a Peltier temperature control system. All tests were performed at 20 °C except for the temperature sweep. The oscillatory stress sweep range was set from 0.1 to 1000 Pa at 1 Hz and the frequency sweep range was set from 10 to 0.01 Hz at stress inside the linear viscoelastic region. Temperature sweeps from 20 to 90 °C at a heating speed of 5 °C at 1 Hz was carried. The auto-strain option of the rheometer was selected for the temperature sweep to better control the linear viscoelastic response along the entire temperature sweep. Storage (G') and loss modulus (G'') data were recorded by TRIOS software (TA Instruments, Montreal, QC, Canada).

2.8. Dough texture analysis

Texture analysis of the dough was evaluated using a texture analyzer TA. XT plus (Stable Micro Systems Ltd. Surrey, UK), with slight modifications of the method of Sudha et al. (2007). A dough with a diameter of 4 cm and a thickness of 0.6 cm was scooped using a circular mold and placed on the platform, and a cylindrical probe with a diameter of 75 mm (P/75) was used to perform a TPA test. The sample was compressed twice at a rate of 1 mm/s for 5 s and the textural parameters (hardness, springiness, cohesiveness and resilience) were analyzed by Exponent software (version 6.1.4.0, Stable Micro Systems Ltd.).

2.9. Statistics analysis

Each test was performed three times on batches prepared on different days. All results were analyzed by One-way ANOVA in SPSS 8.5. $P <$

0.05 represented a significant difference, and data were represented as mean \pm deviation (SD).

3. Results and discussion

3.1. Spreadability analysis of blends

Spreadability profiles and values of firmness, stickiness, and area under the force-time curve were shown in Fig. 1 and Table 1. Data of emulsion template oleogels (100% ET oleogels) were not shown as they could not be accurately measured due to their inability to evacuate air during measurement. Pure shortening showed the highest firmness and AUC significantly. Both 100% foam template oleogel (FT oleogel) and shortening/oleogel blends showed significantly lower values of firmness and AUC than the control shortening. The firmness values of the shortening/ET oleogel blend were approximately half those of pure shortening, indicating a higher spreadability. Furthermore, the significantly lower firmness and AUC values of the shortening/FT blends compared to the shortening/ET blends indicated that the approach of oleogel preparation significantly affected the blends' texture. Lower firmness values and work of shear indicated more spreadable fat, suggesting that partial (50%) substitution of shortening with oleogel could effectively improve the spreadability. 100% FT oleogels had the highest stickiness, followed by shortening/FT oleogel blend and control shortening. Shortening/ET oleogel blend showed the lowest stickiness.

3.2. Thermal analysis of blends

To further investigate the properties of the oleogel/shortening blends, differential scanning calorimetry was employed to analyze the melting behavior of the different systems. Thermal profile of all samples is shown in Fig. 2. The shortening control sample showed two endothermic peaks, which appeared at approximately 17 °C and 47 °C, respectively. Mattice and Marangoni (2017) described a similar profile when exploring the behavior of different fat sources, where the endothermic peaks of hydrogenated shortening were around 18 °C and 50 °C. Contrary to shortening, in both FT and ET oleogels no thermal transitions were observed in the studied temperature range. In shortening/oleogel blends, a significant change in the shortening calorimetric profile was observed. The second peak becomes smaller and broader in both shortening/oleogel blends (Fig. 2). A significant decrease in enthalpy (from 31 to 13 J/g in 100% ET oleogel and to 11 J/g in 100%

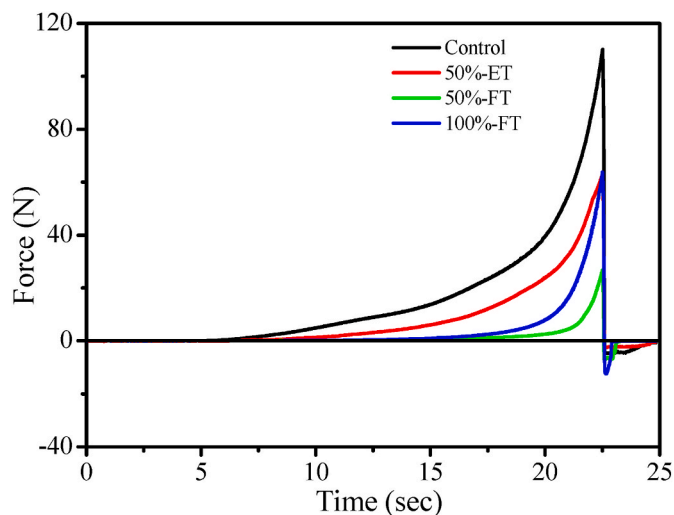


Fig. 1. Spreadability profile of shortening, shortening/oleogel (50/50) blends and 100% oleogel. (Control: shortening; 50%-ET: blend 50% shortening-50% ET oleogel; 50%-FT: blend 50% shortening-50% FT oleogel; 100%-FT: FT oleogel).

Table 1

Values of firmness, AUC and stickiness obtained from spreadability test for control shortening, shortening/oleogel blends and 100% oleogels. ET: emulsion template; FT: foam template.

Sample	Firmness (N)	Area under the curve (N/s)	Stickiness (N)
Control shortening	115.02 ± 10.15 ^a	339.92 ± 50.56 ^a	5.02 ± 1.38 ^c
Shortening/ET oleogel blend	63.85 ± 3.64 ^b	122.72 ± 6.64 ^b	2.35 ± 0.18 ^d
Shortening/FT oleogel blend	26.46 ± 8.69 ^c	27.92 ± 2.32 ^d	7.84 ± 1.03 ^b
100% ET oleogel	–	–	–
100% FT oleogel	65.92 ± 10.86 ^b	97.20 ± 16.54 ^c	12.57 ± 1.83 ^a

^{abcd} For each column, values with different letters are significantly different ($p < 0.05$).

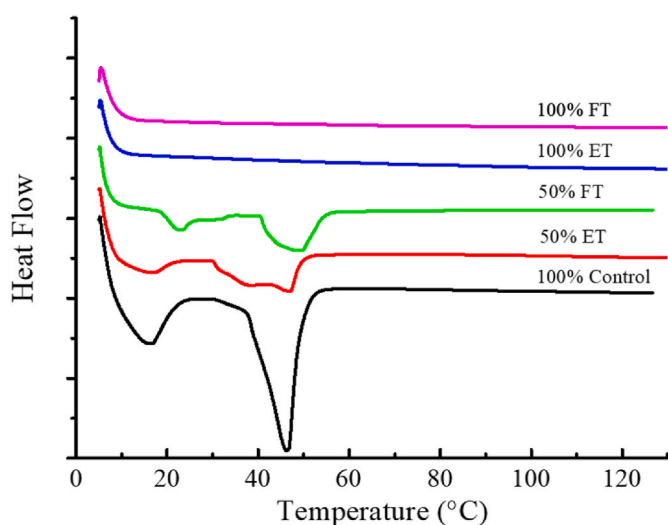


Fig. 2. Thermal profile of control shortening, shortening/oleogel (50/50) blends and 100% oleogel.

FT oleogel) was observed. Also, an increase in melting temperature, with a maximum temperature of the peak from 47 to 48 °C (ET oleogel) and to 50 °C (FT oleogel) (Table 2). The effect of oleogel on the shortening melting temperature and the shape of the melting curve indicated an interaction between the two available matrices of shortening and oleogel, probably due to an alteration of fatty acid composition or in the crystallization behavior of the shortening (Mert and Demirkesen, 2016b), which influenced the thermal profile.

3.3. Rheology analysis of the dough

The effect of total (100% oleogel) and partial (50/50 shortening/oleogel blends) shortening replacement by both FT and ET oleogels in the rheological properties of a puff pastry dough was studied. The effect of stress amplitude, frequency and temperature in the viscoelastic

Table 2

Thermal parameters of control shortening and shortening/oleogel (50/50) blends.

Sample	Peak temperature (°C)	Enthalpy (J/g)
Control shortening	47.0 ± 0.8 ^b	31.1 ± 5.1 ^a
Shortening/ET oleogel blend	48.0 ± 1.0 ^b	13.1 ± 0.2 ^b
Shortening/FT oleogel blend	50.0 ± 0.3 ^a	11.3 ± 0.8 ^c

^{abc} For each column, values with different letters are significantly different ($p < 0.05$).

functions G' and G'' were shown in Fig. 3A. All doughs exhibited solid-like properties with values of storage modulus G' greater than loss modulus G'' over the entire frequency sweep studied. The extension of the doughs' linear viscoelastic region (LVR) became progressively narrower as the shortening level was reduced (higher oleogel content). The shortening sample showed the highest extension of the LVR, followed by the shortening/oleogel blends, being the FT oleogel the one with the lowest resistance to the applied stress. The ET oleogel dough showed a wider LVR than the FT oleogel dough, indicating that the ET oleogel had greater resistance to the applied deformation. The highest spreadability found in the oleogel/shortening blends agrees with the lowest dough resistance to the applied stress.

Fig. 3B showed that both dynamic viscoelastic parameters (G' and G'') of all doughs increased linearly with increasing frequency, indicating a typical viscoelasticity behavior of soft gels. The viscoelasticity and gel strength of the control shortening dough was the highest among all doughs, which might be due to the existence of solid fat crystals and higher aeration (Mert and Demirkesen, 2016b). The highest viscoelasticity of the control shortening dough was in line with the highest hardness and lowest spreadability shown in the texture measurement of control shortening. The replacement of shortening with both oleogels decreased the viscoelastic parameters of doughs, being the G' of doughs prepared with 50% ET oleogels significantly higher than that of 50% FT oleogel doughs (Table 3). The FT oleogel was formed by adsorbing liquid oil through a porous sponge-like cellulose network structure (Jiang et al., 2021; Wang et al., 2023). FT oleogel showed lower oil retention capacity than ET oleogel (Wang et al., 2023). This lower oil retention capacity of the FT oleogel would be related to a higher oil release during the dough rolling, which could coat the flour to form a fatty film, blocking the interaction between gluten proteins and the hydration between proteins and water molecules, thereby inhibiting the formation of gluten and making the dough softer (Ghotra et al., 2002; Mert and Demirkesen, 2016b). Fig. 3C showed the evolution of $\tan \delta$ with frequency, which informs about the viscoelasticity, the ratio between viscous and elastic moduli (G''/G'). Values of $\tan \delta$ were lower than 1 in all the samples, indicating a predominance of the elastic moduli. At 1 Hz, $\tan \delta$ values of all doughs prepared with oleogel were higher (closer to 1) than those prepared with shortening, indicating that shortening induced a higher increase in dough elasticity than both types of oleogel. However, no significant differences in $\tan \delta$ were found between the control shortening dough and shortening/oleogel dough, which indicated that although the incorporation of oleogel decreases the values of G' , no effect in the dough viscoelasticity was found in blends. In the case of 100% oleogel, differences in $\tan \delta$ was significant but small ($\tan \delta$ was 0.39 for control shortening dough, 0.44 for 100% ET oleogel dough and 0.45 for 100% FT oleogel dough), implying that control shortening dough had a higher predominance of elastic behavior. In practice, appropriate dough formation could be carried out with all the fat sources (control shortening, 100% oleogel and 50% shortening/oleogel blends). Therefore, the existing differences in the viscoelastic properties of the dough allow for proper handling, although easier handling was observed in blends in comparison to the 100% oleogel dough. Pehlivanoglu et al. (2018) found similar conclusions when exploring different oleogels as shortening replacers in cakes; oleogels prepared with rice bran and candle wax made the cake batter more appropriate in terms of viscosity.

The effect of oleogel incorporation on the viscoelastic behavior of the dough during heating was shown in Fig. 3D. When the dough was heated, a clearly different behavior was observed between shortening and oleogel doughs. G' decreased with increasing temperature in all the doughs. However, in shortening dough an increase in the slope of the decay of G' was found around 45 °C, revealing the effect of shortening melting. This decrease in G' at 45 °C was accompanied by an increase in G'' , indicating the reduction in the shortening dough viscoelastic properties upon heating.

In 50% and 100% oleogel doughs, the initial soft decrease of G' and G'' before 45 °C was observed, but upon this temperature, no further

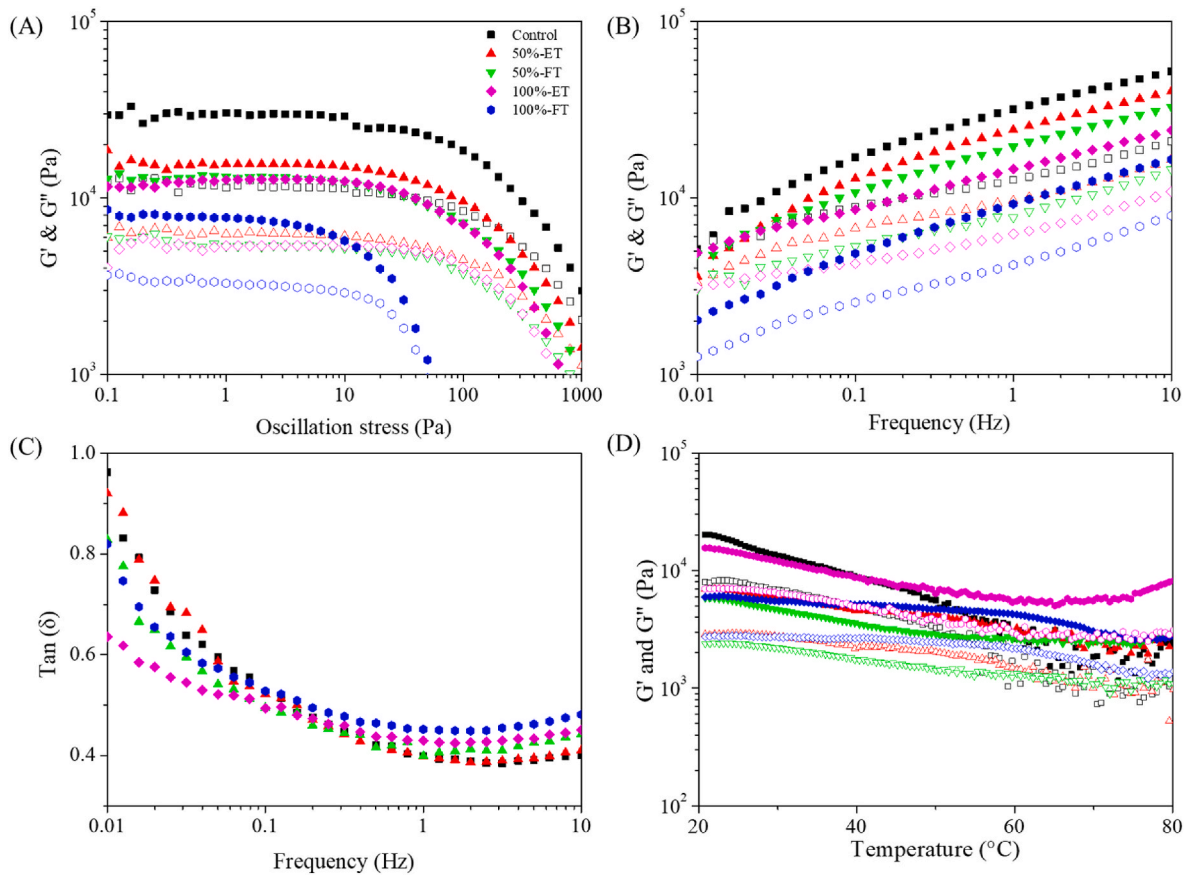


Fig. 3. Rheological properties of dough prepared with shortening, shortening/oleogel (50/50) blends and 100% oleogel as fat sources (■ represents G' , □ represents G''). (A) stress sweep, (B) frequency sweep, (C) loss tangent and (D) temperature sweep. Control: dough with shortening; 50%-ET: dough with 50% ET oleogel and 50% shortening; 50%-FT: dough with 50% FT oleogel and 50% shortening; 100%-ET: dough with ET oleogel, 100%-FT: dough with 100% FT oleogel.

Table 3

Viscoelastic parameters (at 1 Hz) of control shortening dough, oleogel doughs (100%ET or 100%FT), and shortening/oleogel (50/50) blend doughs.

Sample doughs	G' (Pa)	G'' (Pa)	Tan δ
Control shortening	29161 ± 2398 ^a	11533 ± 1063 ^a	0.395 ± 0.004 ^b
Shortening/ET oleogel blend	24312 ± 412 ^b	9771 ± 241 ^b	0.398 ± 0.005 ^b
Shortening/FT oleogel blend	19177 ± 194 ^c	8024 ± 297 ^c	0.419 ± 0.02 ^b
100%-ET	12805 ± 1149 ^d	5663 ± 562 ^d	0.444 ± 0.015 ^a
100%-FT	10021 ± 105 ^e	5157 ± 238 ^e	0.451 ± 0.008 ^a

^{a-e} For each column, means values with different letters indicate significant difference ($p < 0.05$).

decrease was observed, and the viscoelastic functions remained stable. As a consequence of the reduction in the viscoelastic properties of the shortening dough with temperature, at higher temperatures (around 60 °C) the oleogel doughs showed higher viscoelasticity than the control shortening dough. Therefore, shortening replacement by oleogel in dough could improve its thermal stability.

3.4. Texture of the dough

The effect of control shortening, 100% oleogels, and 50/50 shortening/oleogel blends on the puff pastry dough texture properties was shown in Table 4. As well as rheological results, the control shortening

Table 4

Texture parameters of control shortening dough, shortening/oleogel (50/50) blend doughs and oleogel doughs (100% ET or 100% FT).

Sample dough	Hardness (N)	Springiness	Cohesiveness	Resilience
Control shortening	10.60 ± 1.40 ^c	0.53 ± 0.05 ^a	0.51 ± 0.03 ^a	0.123 ± 0.007 ^d
Shortening/ET oleogel blend	6.66 ± 1.00 ^b	0.74 ± 0.16 ^b	0.56 ± 0.07 ^a	0.118 ± 0.024 ^b
Shortening/FT oleogel blend	5.93 ± 0.36 ^b	0.93 ± 0.03 ^c	0.81 ± 0.04 ^b	0.121 ± 0.004 ^c
100%-ET	8.43 ± 0.62 ^c	0.93 ± 0.09 ^{cd}	0.82 ± 0.02 ^b	0.091 ± 0.003 ^a
100%-FT	4.41 ± 0.27 ^a	0.98 ± 0.01 ^d	0.87 ± 0.05 ^b	0.118 ± 0.009 ^b

^{abcd} For each column, mean values with different letters are significantly different ($p < 0.05$).

dough showed the highest hardness (10.60 ± 1.40 N). It is well known that shortening forms a barrier around gluten proteins that prevent extensive cross-linking of the gluten (Mert and Demirkesen, 2016a). The lowest viscoelasticity and the lowest dough hardness in the presence of oleogels, indicated that the oil present in the oleogel avoids the development of the gluten network, even to a greater extent than shortening, creating a softer dough structure than the one created by shortening. Hardness of the dough prepared from the different shortening/oleogel blends decreased to about 6 N. Significant differences were found among the two types of 100% oleogel doughs, being the lowest hardness found in the FT oleogel, which could be explained due to the lowest oil

retention capacity of the FT oleogel, as previously described (Wang, et al., 2023). Lowest oil retention capacity means higher oil loss during rolling dough forming. The release oil could not only inhibit the development of gluten protein but also affect the fluidity and ductility of the dough (Mert and Demirkesen, 2016a), resulting in a loose and soft dough. Accordingly, the dough prepared from 100% FT oleogels had the lowest hardness (4.41 ± 0.27 N), which is also consistent with the results of rheological tests on the dough.

The structural system to fix the oil is different in both types of oleogels. In the foam based oleogel a cellulose porous structure is first formed and the oil trapped in a second step, whereas in the ET oleogel the oil is initially entrapped in an o/w emulsion, and the water evaporated in a second step. In the case of MC and HPMC oleogels the oil retention capacity was initially higher in the ET than in the FT, which will also explain an easier oil release during the FT dough lamination process. Hardness of the dough prepared by the ET oleogel was 8.43 ± 0.62 N, which was not significantly different compared to shortening ($P > 0.05$). The cohesiveness and springiness of the dough increased significantly with a higher degree of oleogel substitution, for both types of oleogels. As for the effect of oleogel on the dough resilience no effect was found.

4. Conclusion

This paper investigated the suitability of HPMC oleogels prepared by the emulsion and the foam template approaches to partial or total replace shortening in a puff pastry dough formulation. Mixing oleogel with shortening increases spreadability, reduces hardness and increases the melting point compared to control shortening. In puff pastry dough, a decrease in viscoelastic parameters and hardness was observed with the incorporation of oleogel, denoting that similarly to the effect of shortening, the oil present in the oleogel interacts with gluten avoiding the development of a strong gluten network. No significant differences were found in viscoelasticity ($\tan \delta$) among the shortening dough and oleogel/shortening doughs. Dough thermal stability was increased in the presence of oleogel, as no fat melting occurs in the absence of shortening. A relationship among the spreadability properties of the shortening, ET oleogel, and shortening/oleogels blends with puff pastry dough texture and rheological properties was found. The most similar behavior to the shortening dough in terms of texture and rheological behaviour was found for the shortening/ET oleogel blend. The difference among the behavior of the FT and the ET doughs was associated to the lowest oil retention capacity of the FT oleogel structure, which will favor oil release during the rolling process necessary to obtain puff pastry doughs.

CRedit authorship contribution statement

Q. Wang: Conceptualization, Methodology, Formal analysis, Writing – original draft, preparation, Writing – review & editing. **M. Espert:** Methodology, Writing – review & editing. **A. Salvador:** Conceptualization, Methodology, Investigation, Funding acquisition, Supervision, Writing – review & editing. **T. Sanz:** Conceptualization, Methodology, Investigation, Funding acquisition, Writing – review & editing.

Declaration of competing interest

The authors declare that there is no conflict of interest.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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