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Effect of Hazelnut Oil and Microencapsulated Hazelnut Oil Usage on Physicochemical and Textural Properties of Cake

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ABSTRACT: Microencapsulation is widely used as an effective method for protecting oils containing unsaturated fatty acids against oxidative deterioration. The use of microencapsulated oil powder can affect the textural and physicochemical characteristics of bakery products. In the present study, microencapsulated hazelnut oil powder (MHOP) was prepared in skim milk powder (SMP) with oil/SMP ratio of 1/1 using a spray dryer. Cakes were produced using only hazelnut oil (control) and also with substitution of hazelnut oil by MHOP at substitution rates of 50% and 100%. The flow properties indicated that the cake batter presented pseudoplastic behavior with the use of MHOP. Consistency index values of the batters were increased significantly ($p<0.05$) with the increase in MHOP substitution. An increase in MHOP-substitution reduced the L^* values of crust and crumb colors. MHOP substitution had a similar effect on the b^* values of crust and crumb color, but the a^* values of crust color did not affect by the MHOP substitution. Moisture content of cakes decreased from 19.06% to 17.30% with increase in the amount of MHOP. The water activity values of cakes were in the range of 0.74-0.75. MHOP substitution was found to be significant ($p<0.05$) in affecting the hardness value of cakes. The highest hardness value of cakes was obtained with a substitution of 100% MHOP. The results showed that certain amounts of MHOP could be used to improve the texture and physicochemical properties of the cake.

Keywords: Batter, cake, microencapsulation, hazelnut oil, texture, viscosity

Fındık Yağı ve Mikroenkapsüle Fındık Yağı Kullanımının Keklerin Fizikokimyasal ve Tekstürel Özellikleri Üzerine Etkisi

ÖZET: Mikroenkapsülasyon doymamış yağ asitleri içeren yağların oksidatif bozulmaya karşı korunması için etkili bir yöntem olarak yaygın şekilde kullanılmaktadır. Mikrokapsüle yağ tozunun kullanımı fırıncılık ürünlerinin tekstürel ve fizikokimyasal özelliklerini etkileyebilir. Bu çalışmada, mikroenkapsüle fındık yağı tozu, yağsız süt tozu ve fındık yağının 1/1 oranında hazırlanması ve püskürtmeli kurutucuya beslenmesiyle elde edilmiştir. Kekler, sadece fındık yağı (kontrol) kullanılarak ve fındık yağı yerine %50 ve %100 oranlarında mikroenkapsüle fındık yağı tozu kullanılarak üretilmiştir. Kek hamuru akış özellikleri mikroenkapsüle fındık yağı tozu kullanımı ile psödoplastik davranış göstermiştir. Hamurun kıvam katsayısı değeri mikroenkapsüle fındık yağı tozu oranının artmasıyla önemli ölçüde artmıştır ($p<0.05$). Mikroenkapsüle fındık yağı tozu oranının artmasına bağlı olarak kek kabuk ve iç renginde L^* değeri azalmıştır. Mikroenkapsüle fındık yağı tozu kullanılması kabuk ve iç b^* değerleri üzerinde de benzer etki göstermiştir ancak a^* değeri üzerinde bir etkisi olmadığı belirlenmiştir. Kek örneklerinin nem değerleri mikroenkapsüle fındık yağı tozunun kullanım oranının artmasına bağlı olarak %19.06'dan %17.30'a azalmıştır. Keklerin su aktivitesi değerleri 0.74-0.75 arasında belirlenmiştir. Mikroenkapsüle fındık yağı tozunun kullanılmasının keklerin sertlik derecesini önemli ölçüde etkilediği bulunmuştur ($p<0.05$). En yüksek sertlik değeri %100 oranında mikroenkapsüle fındık yağı tozunun kullanıldığı kek örneğine aittir. Sonuçlar, kek örneklerinin dokusunu ve fizikokimyasal özelliklerini geliştirmek için belirli miktarda mikroenkapsüle fındık yağı tozu kullanılabileceğini işaret etmektedir.

Anahtar Kelimeler: Kek miksi, kek, mikroenkapsülasyon, fındık yağı, tekstür, viskozite

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INTRODUCTION

Hazelnut (*Corylus avellana*), belongs to the *Betulaceae* family, is widely cultivated in several Mediterranean countries, especially in Turkey (Topkafa et al., 2019). Hazelnut is an important source of energy, which containing 50–73% lipid. Hazelnut oil (HO) contains mono- and poly-unsaturated fatty acids such as oleic and linoleic acids, which are essential for human health. HO may be protective against hypertension, reduce the cholesterol level, and risk of coronary heart disease (Parcerisa et al., 1997; Köksal et al., 2006). HO is used in the production of bakery and chocolate products in the food industry; as well as in other industries such as the cosmetic products (Topkafa et al., 2019). Although its many benefits and wide field of usage, it is very sensitive to lipid oxidation due to high unsaturated fatty acid content. Therefore, the microencapsulation technique can be used to prevent lipid oxidation and quality losses, thereby increasing the shelf life (Kalkan et al., 2017). Microencapsulation is a process by which converts active material into capsules by using a continuous film as a coating material (Aghbashlo et al., 2013). This process protects the active material (oils, flavors, and essential oils) from the external environment (oxygen, moisture, temperature, and light). Especially, the oils with a high content of unsaturated fatty acids are protected against lipid oxidation (Gharsallaoui et al., 2007). There are a variety of techniques for the microencapsulation applications including spray drying, freeze drying, spray cooling/chilling, extrusion, and coacervation (Aghbashlo et al., 2013). Among these methods, spray drying is the most widely used method in the food industry (Gharsallaoui et al., 2007; Kalkan et al., 2017). To be successful in microencapsulation application, the amount of surface oil should be low, and the efficiency must be high (Aghbashlo et al., 2013). The choice of coating material in the microencapsulation applications for high efficiency is very important. The emulsifying properties of the coating material to be selected in the microencapsulation application of oils should be good. The cost of the coating material to be used in the food industry should be low as possible (Gharsallaoui et al., 2007). When these characteristic properties are considered, skim milk powder (SMP) is a significant coating material (Shamaei et al., 2017). SMP is easy to access and is widely used in many food ingredients such as cake, biscuit, ice cream, and margarine.

Research dealing with microencapsulation of oil/fat and its use in the bakery products have very much increased in recent years. Most of the ingredients are used as powders in the bakery industry. However, adding fat to the production system constitutes an extra step in the automated process due to requiring pumping and melting system (Wehrle et al., 1999; O'Brien et al., 2003). The use of microencapsulated oil powder in the formulations allows the fat to be added as a powder, facilitating the production process on the food industry (Wehrle et al., 1999). Besides, it has been reported that the use of microencapsulated oil powder can improve the oxidation stability of the baked product, reduce rancidity, and extend the shelf life (O'Brien et al., 2003; de Almeida et al., 2018; González et al., 2018).

The cake is one of the widely consumed bakery products all over the world because of its affordability, availability, and long shelf life. Fat or shortening plays an important role in cake quality properties. The fat contributes to the incorporation of air during the creaming process and leavens the product. Also, fats are known to increase moistness, prevent the harder crumb, interfere with the continuity of starch and protein particles, and improve the mouthfeel and softness (Rodríguez-García et al., 2012; Pizarro et al., 2013). Fat type and amount affect the batter viscoelastic properties, which have a significant effect on the malleability of batter (Sudha et al., 2014; Guadarrama-Lezama et al., 2016).

The main objective of this research was to evaluate the effect of different amounts of microencapsulated hazelnut oil powder (MHOP) on the viscoelastic properties of batter and textural characteristics of cake in comparison with control which is prepared using only hazelnut oil. The changes in color, a_w, and moisture of cake samples were also determined.

MATERIALS AND METHODS

Material

HO was obtained from Cotanak Oil Company (Ordu, Turkey). Wheat flour, sugar, fresh eggs, skim milk powder, salt, and double acting baking powder were purchased from local markets in Nigde, Turkey. All chemicals used in this study were of analytical grade.

Methods

Hazelnut oil microencapsulation

HO was microencapsulated for adding to the cake batter. For this purpose, an emulsion (30% solid content) was prepared with HO using SMP as coating material (1/1, oil/coating material ratio in solid content). SMP was dissolved in distilled water. HO was added to this mixture (SMP + distilled water), and the emulsion (HO + SMP + distilled water) was homogenized at 24.000 rpm for 7 min using an Ultra Turrax T18 homogenizer (Germany) (Sudha et al., 2014; Jeyakumari et al., 2016). The homogenized emulsion was feed to spray dryer (Buchi B-290, Switzerland) with a 2.8 mm nozzle atomizer. Spray drying process conditions were kept at constant feed rate of 8 ml/min; air flow rate of 600 L/h; inlet temperature of 180°C; and outlet temperature of 91-95°C (Takeungwongtrakul and Benjakul, 2017).

Preparation of cake samples

Cakes were prepared by using the AACC method of 10–91 with some modifications (AACC, 2000). Different formulations were prepared according to the recipe shown in Table 1. Cake without MHOP was used as control. Firstly, oil, sugar, and egg were mixed in kitchen mixer (KitchenAid K45SSWH, St. Joseph, Michigan, USA) at speed 4 for 4 min. SMP, salt, and water were added, then mixing was continued at speed 2 for 1 min, then flour and baking powder were added to form cake batter, and the mixture was mixed at speed 2 for 2 min. Pans with lightly greased were filled with 200 g of batter and baked at 170°C for 25 min in kitchen type conventional oven (Korkmaz A489, Turkey). After baking, cakes were cooled at 25°C for 2 h and stored in air-tight containers until used in analyses.

Table 1. The formulations of cake samples

Ingredients	Control	MHOP Substitution	
		MHOP-50%	MHOP-100%
Flour (g)	45	45	45
Sugar (g)	45	45	45
Egg (g)	20	20	20
Hazelnut oil (g)	10	5	-
MHOP (g)	-	10	20
Skim milk powder (g)	10	5	-
Salt (g)	0.8	0.8	0.8
Double-acting baking powder (g)	2.2	2.2	2.2
Water (mL)	40	40	40

Determination of textural and viscosity properties of cake batter samples

The firmness value of cake batter samples was determined with a PC-controlled TA-XT2i texture analyzer (Stable Microsystems, Godalming, UK) using the TTC Spread-ability Rig (HDP/SR) in four replicates. The firmness test was performed under the following conditions: distance of 16 mm, test speed of 3 mm s^{-1}, post-test speed of 10 mm s^{-1} for 5 s, and load cell of 5 kg.

The viscosity properties of cake batter samples were determined using a rotational viscometer (Brookfield AMETEK, Middleborough, USA). Spindle LV 04(64) was used, and speed was set to 0-200 rpm for all experiments. The measurements were carried out at room temperature (25±1°C). Apparent viscosity (μ_{app}) was predicted by using the power law model constants Eq. (1), where $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency coefficient ($Pa\cdot s^n$), and n is the flow behaviour index (dimensionless).

$$\mu_{app} = K \cdot \dot{\gamma}^{n-1} \quad (1)$$

Characterization of cake samples

Determination of physicochemical properties

The moisture contents of cake samples were determined according to the AACC Method 44–15A (AACC, 2000). Lipid and ash content of cake samples were measured by AOAC Method 920.39 and 942.05, respectively (AOAC, 2005). Petroleum ether was used as a solvent in total lipid determination. The water activity of cake samples was measured by using an automatic water activity device (Novasina, Lachen, Switzerland).

Color measurement

Crumb and crust color properties of cake samples were evaluated using a colorimeter (Konica Minolta CR 400, Japan) based on CIE color values (L^*, a^*, b^*). L^* (brightness/darkness), a^* (redness/ greenness) and b^* (yellowness/ blueness) values were determined. The total color difference (ΔE) was calculated Eq. (2), where L_0 , a_0, and b_0 are color properties of control sample.

$$\Delta E = \sqrt{(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2} \quad (2)$$

Textural measurement

The texture profile analysis (TPA) of cake samples (the midsection of the cakes; 1×1×1 cm) was performed using a texture analyzer (TA-XT Plus, Stable Micro Systems Ltd., Surrey, UK) with a 35 mm diameter cylindrical probe (P/35). Texture parameters were evaluated on cakes stored after 24 h in plastic bags at 25°C. Test parameters were 50% compressing, test speed of 1.0 mm s^{-1}, pre-test, and post-test speed of 2.0 mm s^{-1}, and trigger force 5 g. The texture parameters were recorded as hardness, cohesiveness, springiness, resilience and chewiness.

Statistical Analyses

Values were expressed as the mean ± standard deviation. Results were analyzed using a One-way analysis of variance (ANOVA) and Duncan test using SPSS (version 15.0, SPSS Inc., USA) with 95% confidence level. Pearson's correlation matrix was used to understand the relation between batter and cake properties by XLSTAT 2014 software (add-on for Microsoft Excel® of Microsoft Corporation, USA). The significance level was set at $p<0.05$.

RESULTS AND DISCUSSION

Textural and Viscosity Properties of Cake Batter Samples

The rheological properties of cake batters were investigated by using changed shear stress depending on the shear rate. The consistency index (*K*) and flow behavior index (*n*) values are shown in Table 2. It was found that cake batters with or without MHOP were provided fit for the Power Law Model. The substitution of MHOP significantly ($p<0.05$) increased the consistency index of the batter. Change in cake batter's viscosity might be attributed to oil content. These results are consistent with Sakiyan et al. (2004), who observed that the increase in fat content led to raising the amount of entrapped air in the structure of cake batter, so viscosity decreased. Qasem et al. (2017) also reported the lower viscosity had been caused by the lubrication effect of dispersed fat particles within molecules. It was observed in Fig. 1 that the apparent viscosity of cake batters decreased as the shear rate increased; thus, the batter formulations exhibited pseudoplastic behavior. In addition, there is a difference between the apparent viscosities of cake batters containing the MHOP and control cake batter. The substitution of MHOP in batter formulation increased the apparent viscosity and consistency index, which indicated that the replacement of MHOP enhanced pseudo-plasticity. The flow behavior index of all the cake batters was less than 1 (Table 2), which means batters exhibited shear thinning. The MHOP substitution led to a significant decrease in flow behavior index; by supporting the shear thinning behavior. Qasem et al. (2017) have reported that the flow behavior index was increased with higher air incorporation in the cake batter. This is in agreement with the ability of the oil to increase the level of entrapped air of cake batters reported by Sakiyan et al. (2004).

Table 2. Effect of MHOP substitution on textural and properties of cake batter

Sample	Rheological properties			Textural properties
	K (Pa.s^n)	*n*	R^2	Firmness (N)
Control	15.52±0.41^c	0.304±0.01^a	0.96	1.11±0.08^b
MHOP-50	28.06±0.70^b	0.058±0.01^b	0.96	2.20±0.06^a
MHOP-100	29.45±0.54^a	0.037±0.01^b	0.98	2.18±0.08^a

^{a,b,c} Values with different letters within a column are significantly different ($p < 0.05$)

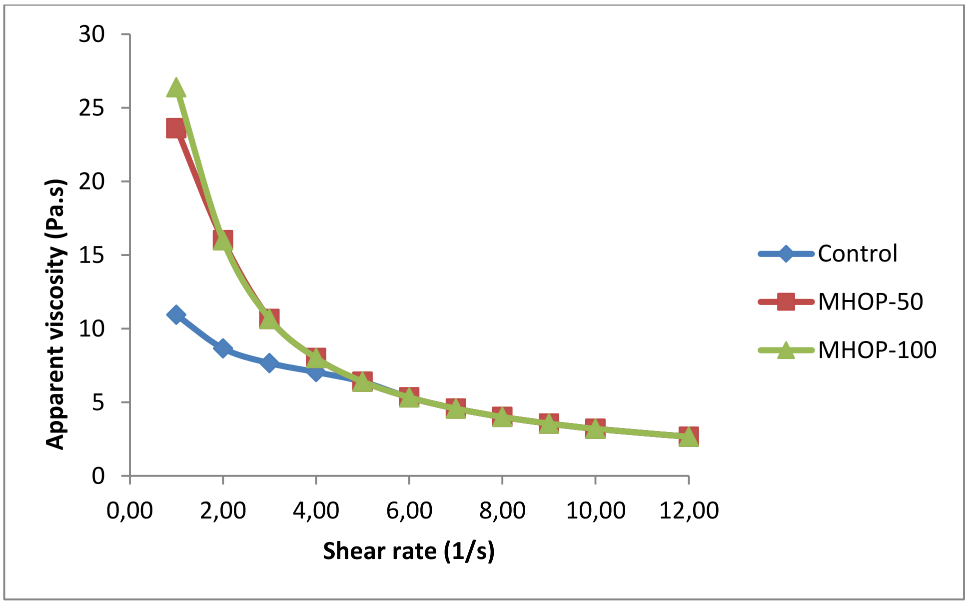

Figure 1. Apparent viscosity of cake batter

The firmness value for cake batters increased as the MHOP replacement, as it can be seen in Table 2. Control cake batter had softer texture compared to MHOP containing samples ($p<0.05$). It could be related to oil, which affected the fluidity and plasticity of the batter. When sufficient oil is present in cake batter, the structure of cake batter becomes softer (Ang et al., 2017). Sudha et al. (2014) have observed that biscuit dough hardness increased when using the encapsulated fat containing sodium caseinate and SMP as a coating material. In addition, it was reported that the fat contributes to the formation softer dough due to inhibiting the gluten network development (Sudha et al., 2014). Furthermore, O'Brien et al. (2003) have reported that the water requirement of the fat powders might be led to increase the batter hardness.

Physicochemical Properties of Cake Samples

The moisture contents of cake samples were observed in the range of 17.30 – 19.06%. It can be seen from Table 3 that the moisture content of the control sample was not significantly different from that of cake containing MHOP at the level of 50%. Cake samples containing MHOP-100 had the lowest moisture content and a_w value. It may be attributed to free water presented in MHOP-100 compared to others. While the used dry matter was the same amount in three formulations, a_w and moisture content of cake samples were different, which may be resulted from the difference in used oil and SMP forms in formulations. Takeungwongtrakul and Benjakul (2017) have reported that using of free oil or microencapsulated oil powder could influence water retention capacity. The moisture content might also be affected by the presence of SMP in the form of free or microcapsule. The total lipid content of cake samples was different significantly ($p<0.05$) due to use of different oil forms in formulations. The ash content for cake samples was statistically insignificant ($p>0.05$).

Table 3. Physicochemical properties of cake samples

Sample	Moisture (%)	Water activity	Total lipid (%)*	Ash (%)*
Control	19.06±0.72^{a}	0.75±0.01^{a}	10.90±1.10^{a}	2.01±0.10^{a}
MHOP-50	18.46±0.63^{ab}	0.75±0.01^{a}	9.31±0.24^{b}	2.12±0.12^{a}
MHOP-100	17.30±0.62^{b}	0.74±0.01^{b}	6.28±0.19^{c}	2.21±0.14^{a}

^{a,b} Values with different letters within a column are significantly different ($p < 0.05$), * dry basis

Color Properties of Cake Samples

Table 4 shows the color properties of the cake samples. The L^* values of cake crust and crumb samples were in the range of 53.34 to 56.01 and 72.49 to 73.93, respectively. The L^* value is an indicator of brightness-darkness. When the crust and crumb color of MHOP-100 and control sample was compared, it was observed a significant difference in the L^* parameter. The result indicated that using 100% microencapsulated oil powder contributed to the more effective color change during baking, similar to the result was found by de Almeida et al. (2018), who reported that microencapsulated chia oil powder for cookie production has led to obvious color change. Jeyakumari et al. (2016) also reported that cookies containing microencapsulated fish oil powder showed a lower L^* value than the fish oil. Furthermore, the decrease in brightness (L^*) value might be related a_w, since Maillard reaction and caramelization were affected by a_w during baking (Wehrle et al., 1999; Umesha et al., 2015). Wehrle et al. (1999) reported that higher a_w value contributed to producing more brightness biscuits. Cake crust containing HO had the highest b^* value. For cake crumb color, α^* values ranged from -1.93 to -1.73, respectively. The MHOP-100 sample had lower α^* value than the control sample, indicating the redness value was decreased with substitution of MHOP.

Table 4. Color properties of cake samples

Sample	Crust Color				Crumb Color			
	*L**	*a**	*b**	*ΔE*	*L**	*a**	*b**	*ΔE*
Control	56.01±1.84[a]	11.65±0.66[a]	38.84±0.65[a]	---	73.93±0.63[a]	-1.73 0.11[a]	21.63±0.64[a]	---
MHOP-50	55.03±0.51[ab]	10.98±0.22[a]	34.50±1.93[b]	5.00±0.88[b]	73.84±0.22[ab]	-1.91±0.10[b]	21.63±0.22[a]	1.47±0.61[a]
MHOP-100	53.34±1.06[b]	11.89±0.43[a]	33.75±1.29[b]	3.12±0.77[a]	72.49±0.98[b]	-1.93±0.40[b]	20.32±0.21[a]	1.98±0.73[a]

[a,b] Values with different letters within a column are significantly different ($p < 0.05$)

Textural Properties of Cake Samples

Textural properties of cake samples in terms of hardness, springiness, cohesiveness, chewiness, and resilience value for each cake sample are shown in Table 5. Results indicated that hardness, cohesiveness and chewiness value of cake samples had significant differences ($p<0.05$). The increase in hardness value could be related to coating material (SMP) since it increased the total solid content of final product. Similar results were observed by Takeungwongtrakul and Benjakul (2017) in biscuits prepared using microencapsulated shrimp oil powder. It was reported that the protein increased the strength of biscuit structure when the protein used as a coating material due to it distributed more efficiently. In addition, the hardness value might depend on the form of oil. The hardness values were higher when used HO in the encapsulated form, as can be seen in Table 5. Oil droplets might reduce the interaction of dough; thus, the hardness value was decreased (Takeungwongtrakul and Benjakul, 2017). Besides, the increase in the hardness may be attributed to moisture content (Takeungwongtrakul and Benjakul, 2017). An increase in MHOP content may result in a decrease in moisture content, which caused the higher hardness value. MHOP-100 which was the hardest sample had the highest value in chewiness. Similarly, O'Brien et al. (2000) observed a lower chewiness value than using microencapsulated fat powder when free fat was used in bread production. Furthermore, Rahmati and Tehrani (2014) reported that higher chewiness value was associated with increasing hardness in cake samples. Cohesiveness value was a measure of the internal resistance of food structure (Lu et al., 2010). TPA results showed that an increase in the cake cohesiveness with increasing MHOP substitution; consequently, the strength of internal bonds increased, and the structure became stronger.

Table 5. Textural properties of cake samples

Sample	Hardness (g)	Springiness	Cohesiveness	Chewiness	Resilience
Control	852.71±13.88[c]	0.89±0.02[a]	0.60±0.00[c]	457.42±3.20[c]	0.34±0.01[a]
MHOP-50	1136.16±45.66[b]	0.92±0.01[a]	0.64±0.01[b]	660.93±28.04[b]	0.36±0.01[a]
MHOP-100	1310.93±32.06[a]	0.90±0.01[a]	0.66±0.02[a]	779.15±14.27[a]	0.37±0.03[a]

[a,b,c] Values with different letters within a column are significantly different ($p < 0.05$)

The relation between batter viscosity and cake properties (texture and moisture) is shown in Table 6 by Pearson's correlation matrix. It was clear that batter characteristics have affected the cake textural properties. Consistency index ($r=0.95$, $p<0.01$) and firmness ($r=0.90$, $p<0.05$) properties influenced the hardness of cake samples to a greater extent when compared to cohesiveness. The viscosity properties of the batter positively correlated with the textural properties of the cake. Thus, firmer batters resulted in a harder cake. Furthermore, it can be observed that Pearson's coefficient ($r=0.99$) presented a significant correlation between consistency index and firmness ($p<0.0001$). However, cake moisture value was found to be related to a lesser extent to textural properties. Cake moisture value was negatively and significantly correlated to cohesiveness ($r=-0.85$, $p<0.05$).

Table 6. Pearson's correlation matrix

Variables	Consistency index	Firmness	Hardness	Cohesiveness	Gumminess	Chewiness	Moisture
Consistency index	1						
Firmness	0.9906	1					
Hardness	0.9460	0.8987	1				
Cohesiveness	0.8150	0.7826	0.8587	1			
Chewiness	0.9489	0.9123	0.9857	0.9257	0.9963	1	
Moisture (%)	-0.7645	-0.7054	-0.7904	-0.8517	-0.8237	-0.8118	1

CONCLUSION

In conclusion, the use of microencapsulated oil powder had significant effects on the texture and viscosity properties of cake and batter. It had also impact on physicochemical properties of cakes. The percentages of microencapsulated oil powder affected markedly the hardness, chewiness, color, and moisture of the cakes. Hence, MHOP can be added to enhance resilience, cohesiveness, and chewiness properties in cakes. In addition, oil microencapsulation can be a useful tool in commercial cake production as its powder form is easy to use in the process.

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