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FOOD AND FEED RESEARCH
Journal of the Institute of Food Technology – FINS
University of Novi Sad
ISSN
2217-5369
(print version ceased in 2023)
2217-5660 (online)

UDK 664.933:637.514.9]:637.043
Original research paper
https://doi.org/10.5937/ffr0-53974

FAT CONTENT MODIFICATION IN CHICKEN LIVER PÂTÉ USING AN OLEOGEL AND A VEGETABLE PUREE

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Abstract: This study investigated the impact of using oleogel made with sunflower oil and vegetable puree on the quality of chicken liver pâté. In this experiment, beef fat was partially or completely replaced with oleogel at 50% (O5) and 100% (O10). Additionally, in the oleogel-enriched samples (OS5 and OS10), chicken liver was substituted with vegetable puree by 15%. All substituted groups showed a significant reduction in total fat content while exhibiting a significant increase in protein content. The L* values showed that O5 and O10 samples maintained higher lightness during storage ($p<0.05$), with O5 being the most stable. Samples with vegetable puree had consistently lower lightness, but higher redness and yellowness. Cooking loss increased progressively with the higher substitution ratios. The TBARS results suggested that formulations with vegetable puree (O5S and O10S) exhibit significant antioxidative effects, reducing lipid oxidation regardless of the oleogel content. Replacing beef fat with the oleogel at 50% or 100% substitution level resulted in a softer texture with lower cohesiveness, gumminess and chewiness except for OS10.

Key words: *liver, pâté, oleogel, substitution, vegetable-based*

INTRODUCTION

Liver pâté is a spreadable meat product made from animal fat, liver, salt, and spices. Widely popular for its culinary significance, it is also known for its high saturated fat content. The global demand for meat products with low saturated fat content is intensifying as the consumer consciousness of their health increases (Barbut, Tiensa, & Marangoni, 2021). When replacing animal fat with plant-based oils in meat products such as sausages, burgers, and pâtés, it is essential to balance maintaining the desirable quality characteristics of these products and improving their health profile (Jimenez-Colmenero et al., 2015). Directly substituting animal fat with plant-based oils can lead to issues with the physicochemical properties (such as texture and stability) and sensory quality (such as flavour and mouthfeel) of the product (Heck et al., 2017; Heck et al., 2019).
Oleogelation is a process where plant-based oils are turned into anhydrite, viscoelastic structures that can maintain shape with the help of “oleogelators” (Liu et al., 2024; Puşcaş, Mureşan, Socaciu, & Muste, 2020). By

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substituting animal fat with oleogels, it is possible to decrease the total fat content and improve the fatty acid profile of meat products without sacrificing textural and sensory attributes (Martins, Vicente, Cunha & Cerqueira, 2018; Moghtadaei, Soltanizadeh, Goli & Sharifimehr, 2021). Barbut and Marangoni (2019) explored replacing pork fat with organogels in pâtés, ethylcellulose-based organogels reduced saturated fat by 62% and had positive sensory results but increased susceptibility to oil separation. Županjac, Ikonić, Šojić and Đermanović (2023), reported that the use of candelilla vax oleogel instead of pork back fat in pork liver pâté caused a darkening of the colour. They suggested that this effect was due to the colour of the added oleogel. According to the study by Franco et al. (2019) quality parameters of pork pâté such as color, were not significantly improved, with linseed oleogel contributing to an increase in yellowness.

Furthermore, the oleogel addition resulted in higher values for cohesiveness, gumminess, and chewiness. Low-quality oleogels can lead to technological issues, including improper drying, a greasy appearance, delamination, and other defects (López-Pedrouso, Lorenzo, Gullón, Campagnol, & Franco, 2021). Wolfer, Acevedo, Prusa, Sebranek and Tarté (2018) found that using 10% rice bran wax with soybean oil as a replacement for animal fat in frankfurters accelerated oxidative changes.

Palamutoğlu (2021) reported that replacing fat in meatballs with an oleogel made from a mixture of sunflower oil and black seed oil gelled with carnauba wax resulted in higher TBARS values in the oleogel-substituted samples compared to others by the end of storage.

The objective of this study was to observe the physicochemical and oxidative effects of decreasing the total fat of chicken liver pâté by substituting both the liver and animal fat portion of the product with vegetable puree mixtures and sunflower oil-based oleogel structures respectively.

MATERIALS AND METHODS

Beef fat and chicken liver were obtained from a local butcher, and vegetables were sourced from a supermarket. The analysis used analytical-grade chemicals that were purchased from Sigma-Aldrich Chemie GmbH, Germany.

Preparation of oleogel

To prepare the oleogel, carnauba wax (10% w/w) was dissolved in sunflower oil using a magnetic stirrer and heated at 140 °C for 30 minutes. The oleogelation process was then refined and completed using a Thermomix TM5 (Vorwerk, Wuppertal, Germany). During this process, the water phase was slowly added to the oil phase, which was kept at 30 °C, with a stirring speed of 3 for 3 minutes, achieving an addition rate of approximately 33.3 ml/min. Next, the oleogel was emulsified at high speed (setting 7) for 8 minutes to ensure complete formation. The resulting oleogel was then transferred into clean jars and left to set for 24 hours at 4 °C.

Preparation of liver pâté

In this study, different formulations of liver pâté were prepared to evaluate the effects of fat replacement with oleogel and the incorporation of vegetable puree. The control sample (C) was formulated using 100% beef fat (BF). In the O5 formulation, 50% of the beef fat was replaced with oleogel (OJ), while in the O10 formulation, 100% of the beef fat was replaced with oleogel. Additionally, to examine the combined effect of fat replacement and vegetable puree addition, OS5 and OS10 formulations were developed. In OS5, 50% of the beef fat was replaced with oleogel, while 15% of the chicken liver (CL) was replaced with vegetable puree (VP). Similarly, in OS10, 100% of the beef fat was replaced with oleogel, and 15% of the chicken liver was replaced with vegetable puree. These formulations were designed to investigate the impact of oleogel and vegetable puree on the physicochemical and textural properties of liver pâté during storage.

The formulations of the pâté samples are provided in Table 1. Beef fat was placed in vacuum-sealed bags and heated in a water bath at 100 °C for 20 minutes to soften. The vegetables (17% celery stalks, 50% carrots, and 33% red bell peppers) were peeled, diced into 1 cm cubes, and blended using a high-power blender (ConAir 7011G, Waring Laboratory Blenders, USA) until a smooth, particulate-free consistency was achieved. Chicken liver (CL), salt, and sodium nitrate were processed in the blender at speed 1 for 2 minutes and then stored in sanitized jars at 4 °C for 5 hours. The raw ingreients were added to the Thermomix TM5

Table 1.
Formulation of pâté samples

Ingredients (g)	Experimental group (batch)				
	C	O5	O10	OS5	OS10
Chicken liver (CL)	576	576	576	490	490
Beef fat (BF)	576	288	-	288	-
Oleogel (OG)	-	288	576	288	576
Vegetable puree (VP)	-	-	-	86	86
Salt	22	22	22	22	22
Spice mixture	12	12	12	12	12
Sodium caseinate	12	12	12	12	12
Sodium nitrate	0.24	0.24	0.24	0.24	0.24

C: control 100% BF; O5: 50% BF+50% OJ; O10: 0% BF+100%OJ; OS5: 50% BF+50% OJ+15%VP; OS10: 0% BF+100%OJ + 15%VP

(Vorwerk, Wuppertal, Germany) followed by the other ingredients (as shown in Table 1). The mixture was processed at speed settings 3 and 45 °C for 15 minutes before being vacuum-sealed. The vacuum-sealed bags were then cooked sous-vide at 76 °C until the core temperature reached 70 °C. After cooking, the bags were cooled to room temperature and stored at 4 °C until analysis. pH, colour, and TBARS analyses were conducted on liver pâté samples on days on days 0, 3, 6, 9, 12 and 15.

pH value and chemical composition

pH value of liver pâté samples was measured using a pH meter (WTW pH3110 set 2, Geotech, Denver). The protein content was determined with the Kjeldahl method. Fat content was determined according to Flynn & Bramblett (1975). Moisture and ash content were analysed according to AOAC (2005) guidelines. The carbohydrate content was calculated by subtracting the sum of the other components from 100. The energy value (kcal/100g) of the samples was calculated based on the European Parliament regulation (2011) by using Atwater values corresponding to fat (9 kcal/g), protein (4.02 kcal/g), and carbohydrates (3.87kcal/g) (Mansour & Khalil, 2000). Cooking loss was calculated by comparing the weight of the samples before and after the cooking process.

Colour parameters

Colour parameters of liver pâté samples (L^*, a^*, b^*) were determined using a digital colorimeter (Chromameter CR400, Minolta, Japan). The measurements were conducted under a D65 illuminant with a 100-standard observer on four distinct points from homogeneous and representative areas of each sample surface .

Lipid oxidation assessment

Samples were also assessed for oxidative stability by monitoring changes in the concentrations of 2-Thiobarbituric Acid Reactive Substances (TBARS). The TBARS value was determined using the method outlined by Witte, Krauze and Bailey (1970).

Texture profile analysis (TPA)

The liver pâté samples were gently homogenized and molded into cylindrical shapes (approximately 20 mm height × 20 mm diameter) using a small mold. The samples were then stored at 4 °C for 30 minutes to stabilize their structure before testing. Prior to texture analysis, the samples were brought to room temperature. Texture profile analysis (TPA) was carried out using a texture analyser on storage day 0 (TA-XT2, Stable Micro Systems, Godalming, UK) with a ball probe (P1S, 2.54 cm in diameter), load cell 5 kg, cross-head speed 1 mm/s, and test speed 1 mm/s.

Statistical analyses

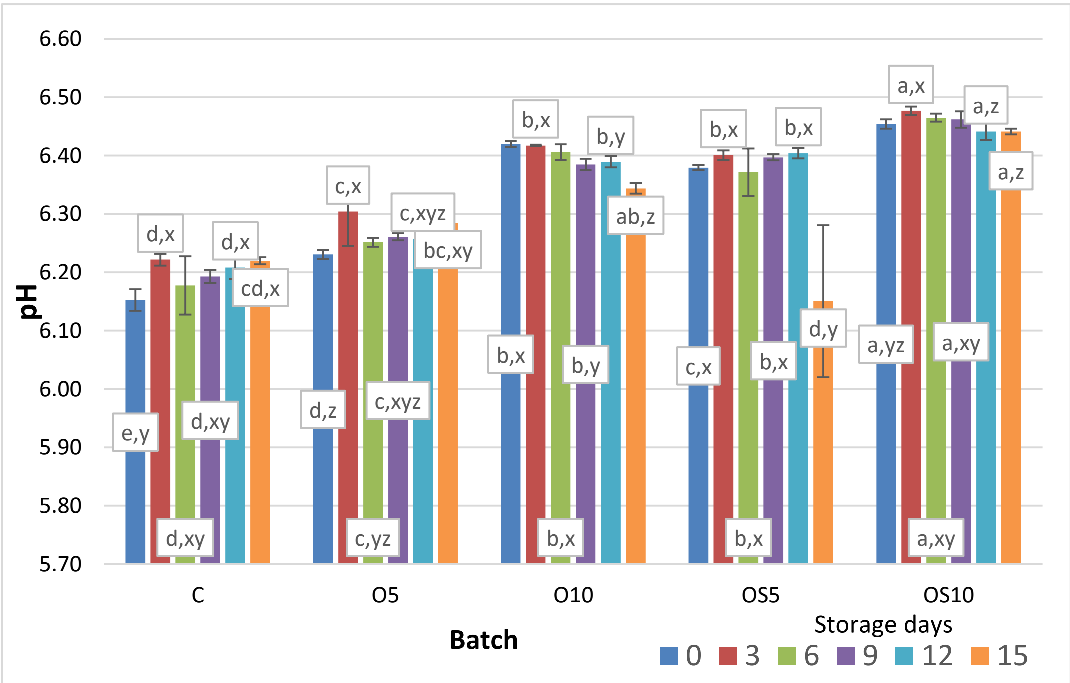
The liver pâté production procedure was replicated twice, resulting in two distinct batches produced on different days. All measurements were repeated three times. Statistical analyses for proximate analyses, TPA and cooking loss were conducted with one-way ANOVA while storage analyses such as TBARS, pH and colour parameters were carried out using two-way ANOVA, all followed by Duncan post-hoc test in SPSS 25.0 statistics software (IBM SPSS Statistics for Windows, version 25.0, IBM Corp., Armonk, NY).

RESULTS AND DISCUSSION

Figure 1 shows the pH changes during the storage of liver pâté. The replacement of beef fat with oleogel and the addition of VP in the formulation was found to affect the pH values of the samples significantly (p<0.05). At the beginning of storage, the lowest pH value (6.15) was observed in the control samples, while the highest pH value (6.45) was found in the OS10 treatment. The addition of oleogel and VP in the liver pâté caused an increase in pH. The highest pH values were observed in OS10 throughout the storage period. This can be attributed to the higher pH value of the oleogel (pH 6.50). Besides this, the added vegetables might release natural alkaline compounds, such as minerals like potassium and magnesium, which can increase the pH of the samples. Additionally, the oleogel matrix could enhance the buffering capacity or stabilize certain components in the vegetable puree, resulting in a slightly higher pH compared to the beef fat matrix. Kenenbay et al. (2023) observed a similar increase in pH values in experimental samples when liquorice root and ginger were added to the liver pâté formulation. A pH level that is distant from the isoelectric point can enhance protein solubility, thereby improving the effectiveness of proteins during emulsification (Lazárková et al., 2023).

At the end of the storage pH values of liver pâté samples ranged between 6.22-6.44. The proximate composition of pâté samples was significantly affected by the incorporation of oleogel. Table 2 shows the chemical composition and energy value of liver pâté samples. The control sample (C) had the lowest moisture content (49.65%), which is expected as it contained 100% beef fat. The moisture content significantly increased in fat-reduced samples (O5, O10, OS5, OS10) due to the replacement of beef fat with oleogel.

The OS10 formulation had the highest moisture content (56.63%), likely due to both 100% fat replacement and the addition of vegetable puree (15%), which contains additional water. Several studies have investigated the effects of replacing animal fat with oleogels on the chemical composition and energy value of liver pâté samples. These studies generally report that such replacements lead to increased moisture content and decreased fat content in the reformulated products.



[a-d]Different letters indicate significant differences between sample means
[x-z]Different letters indicate significant differences between sample means during storage days (p < 0.05)
C: control 100% BF; O5: 50% BF+50% OJ; O10: 0% BF+100%OJ; OS5: 50% BF+50% OJ+15%VP; OS10: 0% BF+100%OJ + 15%VP

Figure 1. pH values of liver pâté samples during the storage

For instance, research indicates that incorporating oleogels into meat products can result in a progressive increase in moisture content and a significant decrease in fat content (Moghtadaei, Soltanizadeh & Goli, 2018, 2021; Martins et al., 2020). The control sample (C) had the highest fat content (27.17%), followed by O5 (20.51%) and OS5 (20.61%), which had 50% fat replacement. The lowest fat content was observed in OS10 (17.10%) and O10 (18.03%), where 100% beef fat was replaced with oleogel.

The addition of vegetable puree (OS5 and OS10) did not significantly affect fat content, as the values were similar to their corresponding O5 and O10 formulations. Protein content increased with fat reduction, likely due to a higher concentration of lean meat relative to fat content in the formulation. The control sample (C) demonstrated the lowest protein content (18.96%) due to being the highest in fat content. The vegetable puree addition in OS5 and OS10 slightly diluted protein content compared to their O5 and O10 counter-parts. The highest ash content was shown in pâté samples OS5 (2.60%) and OS10 (2.58%), indicating that vegetable puree may have contributed additional minerals to these formulations. Samples O5, O10, OS5, and OS10 had significantly higher carbohydrate content (2.11%–2.57%), which can be attributed to oleogel and vegetable puree incorporation. Samples O10 (263 kcal) and OS10 (249 kcal) had the lowest energy values, reflecting their 100% fat replacement. Colour values expressed by *L** (lightness), *a** (redness) and *b** (yellowness) are shown in Table 3. On days 0 and 3, the OS5 and OS10 samples were darker in colour compared to the other samples. At the end of storage, the L* values of the control, O10, and OS5 samples were similar. The L* values of the OS10 samples remained unchanged throughout the storage period. Storage time generally led to darkening in all samples, with the control and O5 experiencing the most fluctuations. OS10 was the darkest sample from start to finish, while O5 was initially the brightest but lost its advantage over time.

The fluctuations observed in the control and O5 samples could be due to the varying stability of fat-based components, whereas OS10's consistent darkness suggests that the presence of VP helped maintain a stable colour profile over time. These findings highlight that oleogels contribute to a lighter appearance, while vegetable puree darkens the product, significantly affecting the visual characteristics of the pâté during storage. Shao, Bi, Li and Dai (2023) investigated the use of ethylcellulose-based oleogels (6%–12%) made with sunflower, peanut, corn, and flaxseed oils in sausages and reported that increased levels enhanced brightness. The a* values revealed that pâté samples with vegetable puree consistently exhibited the highest redness throughout the 15-day storage period.

This demonstrates the significant contribution of vegetable pigments to the colour intensity. Redness in OS5 and OS10 fluctuated slightly but remained high, while the other samples displayed more stable but lower redness values. The b* values revealed significant differences among the pâté samples over the 15-day storage period ($p < 0.05$). Samples containing vegetable puree exhibited the highest yellowness, with OS10 maintaining the most intense and stable values throughout storage. The control sample (C) consistently had the lowest b* values, indicating the least yellow appearance, with values ranging from 11.71 to 13.34. These results demonstrate that the inclusion of vegetable puree significantly enhances the yellowness of the pâté, contributing to a more vibrant appearance compared to the control and O5 and O10 samples. According to the findings of Županjac et al. (2023) the incurporation of oleogels in liver pâté formulations influenced its color, making it darker, redder, and more yellow than the control, likely due to the properties of the oleogel. Oleogel prepared with chicken skin and corn oil was used to replace animal fat in meat batters, resulting in higher L* and b* values and lower a* values compared to the control samples (Serdaroğlu, Yüncü-Boyaci, Turgut, Çalişkan and Can (2024).

The cooking loss is presented in Fig. 2. The cooking loss of the samples ranged from 19.33% to 24.42%. The control sample had the lowest cooking loss, likely due to the high fat content and stability provided by beef fat, which helps retain moisture during cooking. In sample O5 cooking loss increased slightly to 20.52%, reflecting the partial replacement of beef fat with oleogel, which, while mimicking some properties of animal fat, may not retain moisture as effectively.

Table 2
Chemical composition and energy values of liver pâté samples

Batch	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Carbohydrate (%)	Total energy (kcal)
C	49.65 ±1.30^{c}	27.17 ±0.27^{a}	18.96±0.05^{d}	2.52 ±0.08^{ab}	1.70 ±0.02^{b}	327^{a}
O5	53.10 ±2.02^{b}	20.51 ±0.11^{b}	21.74 ±0.02^{b}	2.54 ±0.03^{ab}	2.11 ±0.21^{a}	280^{b}
O10	54.18 ±1.05^{ab}	18.03 ±0.87^{c}	22.83 ±0.08 ^{a}	2.38 ±0.06^{c}	2.48 ±0.13^{a}	263^{c}
OS5	53.37 ±3.07^{ab}	20.61 ±0.22^{b}	20.95 ±0.03^{c}	2.60 ±0.04^{a}	2.50 ±0.23^{a}	279^{b}
OS10	56.63 ±2.87^{a}	17.10 ±0.20^{c}	21.29 ±0.03^{b}	2.58 ±0.02^{a}	2.57±0.34^{a}	249^{c}

Results are given as mean ± standard deviation (n = 6); $^{a-c}$ Means with the different letters in the same column are significantly different ($p < 0.05$). C: control 100% BF; O5: 50% BF+50% OJ; O10: 0% BF+100%OJ; OS5: 50% BF+50% OJ+15%VP; OS10: 0% BF+100%OJ + 15%VP

Table 3.
Colour parameters of liver pâté samples (*L*, a*, b**)

Colour value	Storage days	C	O5	O10	OS5	OS10
L*	0	54.29±0.59^{b,x}	55.36±0.09^{a,x}	54.96±0.25^{b,x}	53.96±0.38^{c,x}	53.79±0.79^{c,x}
	3	52.15±0.33^{b,c,y}	54.29±0.52^{a,y}	53.46±0.97^{b,y}	52.60±0.08^{c,y}	52.56±0,30^{c,x}
	6	51.85±0.51^{c,y}	55.32±0.07^{a,x}	55.00±0.70^{a,x}	52.36±0.16^{bc,y}	53.07±0.63^{b,x}
	9	53.50±0.89^{ab,x}	53.39±0.21^{ab,z}	54.69 ±0.16^{a,xy}	53.48±0.27^{ab,x}	53.11±0.71^{b,x}
	12	53.08±0.50^{ab,xy}	54.09 0.57^{a,y}	53.75 ±0.12^{ab,y}	53.32 ±0.52^{ab,x}	52.97±0.33^{b,x}
	15	53.54±0.22^{a,x}	52.93±0.33^{b,z}	53.63 ±0.05^{a,y}	53.16±0.09^{a,x}	52.77±0.17^{b,x}
a*	0	7.71±0.39^{b,x}	7.31±0.08^{b,xy}	7.57±0.28^{b,x}	11.38±0.15^{a,y}	11.10±0.59^{a,x}
	3	7.59±0.69^{b,x}	6.98±0.27^{b,y}	6.71±0.63^{b,y}	11.03±0.14^{a,y}	11.77±0.13^{a,x}
	6	7.86±0.26b^{a,x}	7.64±0.60^{b,xy}	6.83±0.27^{b,y}	11.70±0.07^{a,y}	12.37±0.41^{a,x}
	9	7.87±0.12b^{,x}	8.52±0.44b^{,x}	7.69±0.31b^{,x}	11.55±0.61a^{a,y}	11.73±1.30a^{,x}
	12	7.64±0.05b^{,x}	7.94±0.32b^{,xy}	7.44±0.3b^{a,x}	12.83±0.19a^{,x}	12.10±1.17^{a,x}
	15	7.67±0.30b^{,x}	6.99±0.16b^{,y}	7.42±0.13b^{,x}	12.91±0.82a^{,x}	12.73±0.78^{a,x}
b*	0	12.54±0.30^{d,x}	14.40±0.17^{c,x}	14.44±0.21^{c,x}	19.27±0.45^{b,xy}	21.20±0.26^{a,x}
	3	12.72±0.14^{d,x}	13.44±0.12^{c,y}	12.61±0.37^{d,y}	18.37±0.14^{b,y}	20.40±0.21^{a,x}
	6	11.71±0.33^{e,y}	13.91±0.23^{c,y}	12.91±0.14^{d,y}	18.42±0.51^{b,y}	19.96±0.47^{a,x}
	9	12.40±0.41^{d,x}	14.40±0.37^{c,x}	14.26±0.06^{c,x}	19.85±0.42^{b,xy}	20.64±0.03^{a,x}
	12	12.95±0.22^{d,x}	14.45±0.37^{c,x}	14.63±0.05^{c,x}	20.09 ±0.09^{b,x}	20.81±0.17^{a,x}
	15	13.34±0.88^{b,x}	12.78±0.30^{b,z}	12.48±0.23^{b,y}	20.57±0.57^{a,x}	20.80±0.22^{a,x}

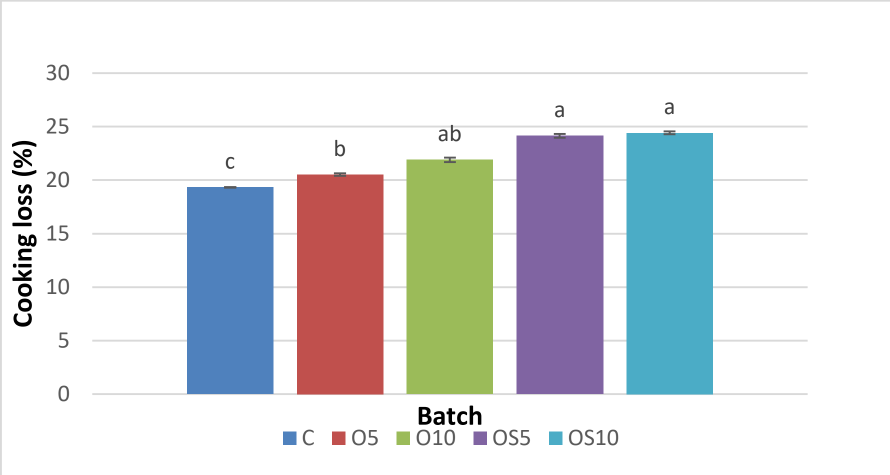
Results are given as mean ± standard deviation (n = 6);. $^{a-e}$ Means with the different letters in the same row are significantly different ($p<0.05$). $^{x-z}$Means with the different letters in the same column are significantly different ($p<0.05$). C: control 100% BF; O5: 50% BF+50% OJ; O10: 0% BF+100%OJ; OS5: 50% BF+50% OJ+15%VP; OS10: 0% BF+100%OJ + 15%VP

Table 4.
Texture profile analyses of liver pâté samples

Batch	Hardness (N)	Springiness	Cohesiveness	Gumminess (N)	Chewinesss (N·mm)	Resillience
C	9.23±0.54^{a}	0.06 ±0.00^{a}	0.09±0.01^{a}	8.38 ±1.08^{a}	0.44 ±0.01^{b}	0.05 ±0.00^{a}
O5	5.43 ±0.76^{c}	0.05 ±0.00^{a}	0.06±0.00^{b}	2.52 ±0.19^{b}	0.12 ±0.02^{d}	0.02 ±0.00^{b}
O10	8.86±0.59^{b}	0.05±0.04^{a}	0.04 ±0.01^{c}	1.21 ±0.18^{c}	0.14 ±0.03^{d}	0.02 ±0.00^{b}
OS5	9.50±0.36^{a}	0.04±0.01^{a}	0.02±0.01^{d}	1.07 ±0.07^{c}	0.20 ±0.02^{c}	0.01 ±0.00^{c}
OS10	4.98±0.23^{c}	0.04±0.01^{a}	0.02±0.01^{d}	1.05 ±0.04^{c}	1.18 ±0.13^{a}	0.01 ±0.00^{c}

Results are given as mean ± standard deviation (n = 6); $^{a-d}$ Means with the different letters in the same column are significantly different ($P<0.05$). C: control 100% BF; O5: 50% BF+50% OJ; O10: 0% BF+100%OJ; OS5: 50% BF+50% OJ+15%VP; OS10: 0% BF+100%OJ + 15%VP

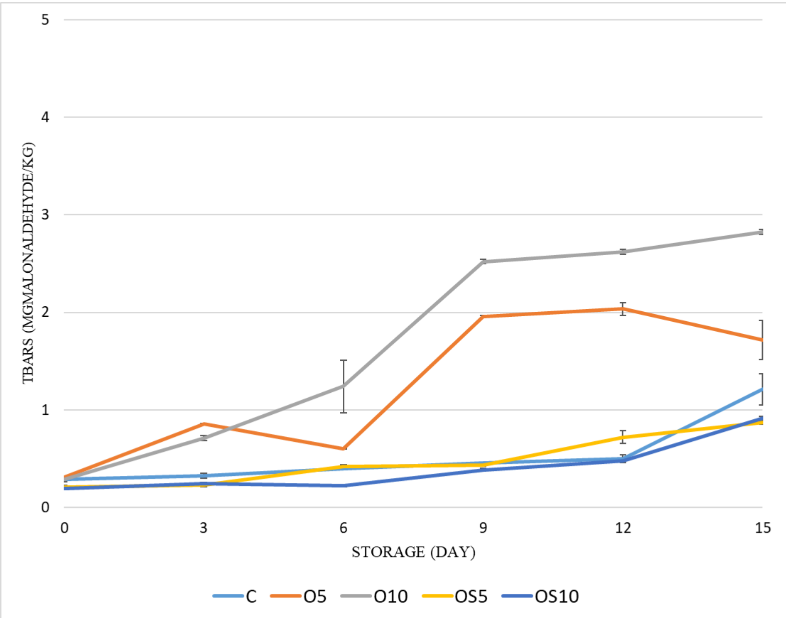
In sample O10 cooking loss further increased to 21.91%, likely due to the e absence of beef fat, which traditionally aids in better moisture retention. The incorporation of vegetable puree in O5S resulted in a significant rise in cooking loss to 24.14%, as the high water content of vegetables contributes to increased moisture loss, especially when combined with oleogel. Sample O10S exhibited the highest cooking loss (24.42%), likely due to the combined effects of vegetable puree's moisture content and the absence of beef fat's stabilizing properties. These results are consistent with the findings of Xiong et al. (2015), who showed that incorporating pre-emulsified plant oils as fat substitutes in spreadable chicken liver pâté increased cooking losses. In their study, substituting animal fat in chicken liver pâté, regardless of the type or quantity of plant oil used, led to a significant rise in cooking loss. In meat products, controlling TBARS value is critical to maintaining product quality, as excessive lipid oxidation can lead to rancidity and reduced consumer acceptance.



C: control 100% BF; O5: 50% BF+50% OJ; O10: 0% BF+100%OJ; OS5: 50% BF+50% OJ+15%VP; OS10: 0% BF+100%OJ + 15%VP

[a-c]Different letters indicate significant differences between sample means

Figure 2. Cooking loss of liver pâté samples



C: control 100% BF; O5: 50% BF+50% OJ; O10: 0% BF+100%OJ; OS5: 50% BF+50% OJ+15%VP; OS10: 0% BF+100%OJ + 15%VP

Figure 3. TBARS values of pâté samples during storage

TBARS values changed between 0.192-2.82 mg MA/kg (Fig. 3). The control sample, formulated with 100% beef fat, showed a gradual increase in TBARS values over storage time. On day 15, the OS5 sample showed the lowest TBARS value, suggesting that the presence of vegetable puree in combination with 5% oleogel helped mitigate lipid oxidation more effectively than other formulations. O5 and O10 samples showed rapid increases in TBARS values, with O10 being the most affected due to the complete absence of beef fat ($p<0.05$). The oxidation progress data corroborates with a similar study where oleogels were used as a fat replacer in model meat emulsion systems (Çalışkan, Yüncü-Boyacı & Serdaroğlu, 2024). Another study by Morales-Irigoyen, Severiano-Pérez, Rodriguez-Huezo & Totosaus (2012) also reported a similar oxidation trend in pork liver pâté samples where fat was replaced with emulsified canola oil. Pușcaș et al. (2020) stated that the use of oleogels as an alternative fat source led to a slower progression of lipid oxidation and lower TBARS values. Vegetable puree significantly mitigates the changes in OS5 and OS10, with OS10 showing the lowest values overall, highlighting the antioxidative benefits of the puree in counteracting the instability of oleogels. No relevant study was found regarding the use of VPs in liver pâté samples, however, the high levels of antioxidative compounds commonly found in red bell peppers (Sun et al., 2007), carrots (Boadi et al., 2021) and celery stalks (Kooti & Daraei, 2017) well documented. However, the inclusion of VP led to lower oxidation levels throughout the storage period compared to the control group. This suggests that VP exhibits antioxidant activity, which helps slow down the accelerated oxidation observed in the control and oleogel-replaced groups.

Spreadability, measured as the work of shear, is a crucial attribute of spreadable products as it reflects how easily the product can be evenly distributed across a surface (Garcia Fontanals, Llorente, Valderraama, Bravo & Talens, 2023).

The control sample (C) made entirely with beef fat, exhibited a high hardness value, similar to that of OS5. Samples O5 and OS10 containing 50% oleogel and 100% oleogel + vegetable puree, respectively, showed significantly lower hardness, indicating that replacing beef fat with oleogel softened the pâté. Similar results were reported by Županjac et al. (2023), who found that replacing pork fat with sunflower oil-based oleogel in pâté formulations resulted in lower hardness values, indicating that the samples had better spreadability. Interestingly, formulation O10, which contained 100% oleogel, had a higher hardness than O5 and OS10.

This suggests that oleogel alone maintains some structural integrity but softens more when combined with vegetable puree (OS10). There were no significant differences in springiness among the samples, with values ranging between 0.04 and 0.06. This indicates that replacing beef fat with oleogel and/or vege-table puree did not significantly affect the elas-ticity of the pâté. The control sample (C) had the highest cohesiveness, followed by the O5 formulation. Samples O10, OS5, and OS10 were significantly lower in cohesisiveness, suggesting that higher levels of oleogel and vegetable puree reduced the internal bonding within the pâté structure. The control sample had significantly higher chewiness than all other treatments. OS5 and OS10 had different responses, with OS10 showing the highest chewiness among oleogel-containing samples, possibly due to the effect of vegetable puree. Added vegetable puree (OS5 and OS10) further weakened the texture, resulting in the lowest values for gumminess, cohesiveness, and resilience. OS10 (100% oleogel + vegetable puree) showed the softest texture but had increased chewiness, suggesting that vegetable puree influenced the mouthfeel differently. While the control maintained the most desirable texture attributes, formulations with oleogels and vegetable puree created a softer and less cohesive texture, suggesting that these healthier alternatives significantly alter the traditional texture profile of pâté and require optimization or better sensory balance. These changes are attributed to the structural differences between beef fat and oleogels, as well as the disruptive effects of water-rich vegetable puree. Our study is consistent with the findings of Morales-Irigoyen, Severiano-Pérez, Rodriguez-Huezo and Totosaus (2012), who reported that the gradual substitution of fat with pre-emulsified oil resulted in a reduction in the hardness of pork liver pâté. According to the findings of Moghtadaei, Soltanizadeh and

Golii (2018), both gumminess and chewiness in raw and cooked burgers were reduced as the percentage of animal fat replacement with BW oleogel increased.

CONCLUSIONS

Fat replacement with oleogel, along with vegetable puree incorporation, can signify-cantly alter the nutritional composition of liver pâté, making it lower in fat and energy while increasing moisture and protein levels. Vegetable puree increased the redness and yellowness of pate samples, while fat replacement with oleogel had a minimal effect on colour. The TBARS results indicated that formulations containing vegetable purees (OS5 and OS10) demonstrated significant antioxidant effects, effectively reducing lipid oxidation regardless of the oleogel content. Fat replacement and vegetable puree incorporation softened the pâté texture. Future investigations should prioritize the optimization of pâté formulations incorporating oleogels and vegetable purees, aiming to achieve a balance between health advantages and product quality. This includes exploring alternative plant-based oils and structuring agents to enhance the oxidative and textural stability of oleogels, as well as evaluating different vegetable types or combinations to improve antioxidant properties and structural integrity.

AUTHOR CONTRIBUTIONS

Conceptualization, M.S.; Methodology, M.S.; Investigation, formal analysis, validation, writing-original draft preparation, M.K.; Writing-review and editing, M.S.; Supervision, M.S.

DATA AVAILABILITY STATEMENT

Data contained within the article.

CONFLICT OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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MODIFIKACIJA SADRŽAJA MASTI U PILEĆOJ JETRENOJ PAŠTETI KORISTEĆI OLEOGEL I POVRĆNI PIRE

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Sažetak: Ova studija je istražila uticaj korišćenja oleogela napravljenog od suncokretovog ulja i pirea od povrća na kvalitet paštete od pileće jetre. U ovom eksperimentu, goveđa mast je delimično ili potpuno zamenjena oleogelom u procentima od 50% (O5) i 100% (O10). Pored toga, u uzorcima obogaćenim oleogelom (OS5 i OS10), pileća jetra je zamenjena biljnim pireom u procentu od 15%. Svi uzorci pašteta sa dodacima pokazale su značajno smanjenje ukupnog sadržaja masti, uz značajno povećanje sadržaja proteina. L* vrednosti su pokazale da su uzorci O5 i O10 imali veću svetlinu tokom skladištenja ($p<0,05$), pri čemu je uzorak O5 pokazao veću stabilnost. Uzorci sa dodatkom pirea od povrća dosledno su bili tamniji, i imali veći udeo crvene i žute nijanse. Gubici pri kuvanju progresivno su se povećavali u uzorcima sa višim udelima substituenata. TBARS rezultati su sugerisali da formulacije sa biljnim pireom (O5S i O10S) pokazuju značajne antioksidativne efekte, smanjujući oksidaciju lipida bez obzira na sadržaj oleogela. Zamena goveđe masti oleogelom (50% ili 100%) rezultirala je mekšom teksturom sa nižom kohezivnošću, gumoznošću i žvakljivošću, osim za formulaciju OS10.

Ključne reči: *jetra, pašteta, oleogel, substitucija, povrće*

Received: *07 October 2025/* ***Received in revised form:*** *15 March 2025/* ***Accepted:*** *17 March 2025*

Available online: *July 2025*

This work was reported at the FoodTech 2024 “Science Today, Technology Tomorrow” congress held in Novi Sad, Serbia, October 16-18, 2024 organized by the Institute of Food Technology in Novi Sad.