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Original scientific paper

Physicochemical and sensory properties of pork liver pâté formulated with sunflower oleogel as fat substituent

Miloš Županjac[a], Predrag Ikonić[a], Branislav Šojić[b] and Branislava Đermanović[a]*

[a] University of Novi Sad, Institute of Food Technology, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia
[b] University of Novi Sad, Faculty of Technology Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia

A R T I C L E I N F O

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A B S T R A C T

This study investigated the effects of back fat substitution with sunflower oleogel on the lipid, moisture and protein content, as well as texture, and color characteristics of liver pâté. Formulations with oleogel had higher lipid content ($p<0.05$) in comparison to control pâté made just with backfat. On the contrary, moisture and protein content were found to be significantly lower ($p<0.05$) in pâté formulated with oleogel compared to the control, regardless the level (%) of substitution. Color analysis revealed that oleogel-added pâté exhibited darker, redder, and more yellow ($p<0.05$) tones compared to the control. Texture analysis showed significant differences ($p<0.05$) in firmness, work of shear, and spreadability. Further research on sensory attributes and consumer acceptance will be performed.

1. Introduction

Pâté, also known as Braunschweiger, is a paste-based meat product with a pleasant flavor and a soft, oily texture that is widely consumed around the world (*Morales-Irigoyen et al.*, 2012). The main ingredients used in the manufacture of pork liver pâté are pork backfat, liver, spices, and, on rare occasions, low-quality meat (*Barbut et al.*, 2021; *Martins*, 2020). Pâtés are commonly known to contain a significant proportion of animal fat, typically ranging from 35% to 50% (*Pan*, 2021). The relatively high fat content in these emulsified meat products affects their sensory, physicochemical, and nutritional properties, as well as their texture (*Rezler et al.*, 2020; *Tobin et al.*, 2013; *Perta-Crisan et al.,* 2023). Saturated fat is the main type of fat found in meat products. However, there is an increasing trend toward healthier meat products with less saturated fat due to the well-documented link between saturated fat consumption and an increased risk of cardiovascular disease (CVD) and other physiological disorders, such as type 2 diabetes, high blood lipid levels, inflammation, and oxidative stress (*Schwingshackl et al.*, 2022; *Maki et al.*, 2021; *López-Pedrouso et al.*, 2021; *Astrup et al.*, 2020; *Silva et al.*, 2023; *Barbut et al.*, 2021; *Mensink et al*., 2016). Although trans and saturated fats have been shown to positively impact the structure and texture of food products (*WHO,* 2013), the World Health Organization suggests limiting dietary fat to 15–30% of total daily energy intake, with saturated fats accounting for no more than 10% of the total (*Badar et al*., 2021; *Lima et al*., 2022; *Khan et al.*, 2015). The reduction of fat in this type of meat product or its replacement with a more unsaturated fat might affect pâté's technological or sensory characteristics. Plant-based oils, which contain a low share of saturated fats and high percentage of unsat-

***Corresponding author:** Miloš Županjac, *milos.zupanjac@fins.uns.ac.rs*

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urated fatty acid (UFA) (monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA)), have enormous potential for use in the production of healthier meat products with improved nutritional quality (*Romanić*, 2020; *Ramadan*, 2020). Sunflower oil is particularly rich in linoleic acid (*Singh et al*., 2017), an essential n-6 polyunsaturated fatty acid, that has been shown to reduce total cholesterol by acting on low-density lipoprotein (LDL), while the level of protective high-density lipoprotein (HDL) remains unchanged (*Guo et al*., 2023).

Cold pressing is a method that provides a secure and non-toxic approach for extracting and processing edible oils. This technique ensures the preservation of bioactive components by avoiding the use of heat, chemicals, and refining procedures (*Demirkesen and Mert*, 2020). Edible oleogels have been developed in response to the trend of substituting animal fat with vegetable oils structured by organogelators (*Patel and Hartel*, 2015; *Perta-Crisan* et al., 2023; *Aranda-Ledesma et al.*, 2022). Oleogels can be described as semi-solid systems with viscoelastic properties and hydrophobic nature, formed by organogelation. Organogelation involves the entrapment of a significant amount of liquid oil, especially vegetable oils, within a three-dimensional network using one or more organogelators (*ISO*, 1997; *Aranda-Ledesma et al.*, 2022). Organogelators can be categorized into different groups, including crystalline particles, low molecular weight compounds, polymers, and inorganic particles (*ISO*, 1978). Candelilla wax (CW) is a plant-derived natural wax obtained from *Euphorbia antisyphilitica* Zucc., a plant species found in the arid regions of northern Mexico. CW has gained attention as a potential organogelator for the creation of food formulations (*ISO*, 1973).

The aim of this study was to investigate how the replacement of pork backfat (lard) with different levels of oleogel affected the physicochemical properties of pork liver pâté.

2. Materials and methods

2.1.1. Raw materials and oleogels production

Pâté formulation comprised the formation of an emulsion constituted from pork backfat, sodium caseinate, hot broth, lean pork meat, chopped liver, salt, spice mix (comprising pepper, dried onion, and marjoram). For the production of Candelilla-based oleogel, a commercial cold-pressed sunflower oil (BISER, Velika Plana, Serbia) was used as the oil phase.

Oleogel with 5% (w/w) of gelator was produced for all the fat replacement experiments. Candelilla wax (Alekpharm, Beograd, Serbia) was dispersed in sunflower oil under stirring at 80°C (above wax melting point) for at least 30 min. After that period of time, the gels were left cooling at room temperature until full gel formation, for at least 24 h.

2.1.2. Pâté manufacturing

Pâtés were prepared using a combination of pork meat, liver, and fat, along with a spice mix (Table 1). The pork meat and fat were boiled in water until they reached a tender state. Subsequently, the meat was mixed with the hot broth obtained from cooking of the meat, and spice mix. Further, the mixture was processed in a Thermomix® TM5 mincer (Vorwerk Elektrowerke GmbH & Co. KG,

Table 1. Formulation of elaborated pâtés.

Raw Materials (%, w/w)	P-CO	P-20	P-40
Pork backfat	40	32	24
Sunflower oleogel	/	8	16
Sodium caseinate	2	2	2
Hot broth	22	22	22
Laean meat	15	15	15
Liver	18	18	18
Nitrite curing salt	2	2	2
Spice mix	1	1	1

P-CO: control **pâté**;
P-20 and P-40: **pâté** with 20% and 40% of pork fat replacement, respectively.

Wuppertal, Germany) at a temperature of 55°C, velocity set at position 6, for 10 minutes. At this stage, homogenized raw pork liver was also added. Oleogel was added to the minced meat and the grinding operation was continued until homogeneous consistency was obtained. Finally, the resulting mass was stuffed into 200 ml jars and cooked until a core temperature exceeded 80 ºC for a period of 3 minutes. The prepared pâtés were subsequently cooled using cold water and stored in a refrigerator prior to further analyses.

2.1.3. Chemical composition of elaborated pâtés

The moisture, protein, and fat content were analyzed using the methods outlined by the International Organization for Standardization (ISO) in ISO 1442 (*ISO*, 1997), ISO 937 (*ISO*, 1978), and ISO 1443 (*ISO*, 1973) procedures, respectively.

2.14. Textural and color analysis

The textural characteristics of the pâtés were assessed using a Texture Analyzer TA.XT Plus texturometer (Stable Micro System, England), following the Margarine Spreadability method — MAR4_SR.PRJ. This method involves employing the Spreadability Rig HDP/SR accessory, comprising an upper conical measuring component affixed to a metal platform. The accessory is calibrated to maintain a height of 30 mm above the static component, which consists of a conical cup. Throughout the measurement, the distance between the upper and lower parts of the accessory remained constant at 23 mm. The analysis employed the following parameters: a 5 kg load cell, a temperature of 22°C, a pre-analysis test speed of 1.0 mm/s, an analysis test speed of 3.0 mm/s, and a post-analysis test speed of 10.0 mm/s. The measurement involved monitoring the force exerted during penetration until it reached its maximum depth. The force values at specific penetration depths corresponded to the hardness of the spread, while the area under the force-time curve represented the work of shearing.

Color measurements were conducted on the pâtés using a portable colorimeter (CR-400, Konica, Minolta, Tokyo, Japan) equipped with a light protection tube (CR-A33b). The colorimeter employed a 0 degrees viewing angle geometry and an 8 mm aperture size. The measurements were performed after the canning procedure to assess the pâté color in the CIELAB color space, specifically the lightness (L^*), redness (a^*), and yellowness (b^*) values. Three distinct points on each sample were selected from homogeneous and representative areas.

2.1.5. Statistical analysis

Statistical analysis was done using Factorial ANOVA (Statistica 14.0.0.15 — TIBCO Software Inc., USA). Duncan's post hoc test was performed for comparison of mean values. Differences were considered significant at $p<0.05$.

3. Results and discussion

The total lipid content primarily consisted of the fat used, with smaller contributions from the liver and muscle. In the oleogel formulations, the lipid content (P-20: 39.21±0.22[a] and P-40: 39.69±0.20[a]) was higher compared to the backfat formulation, which had a significantly lower ($p<0.05$) fat percentage (34.55±0.56[b]). These observations can be explained by the compositions of both the sunflower oil, used for the oleogel preparation, and the backfat. Sunflower oil contains 99.90% lipids, while backfat, besides fat, also contains smaller proportions of proteins and moisture.

Table 2. Chemical composition of pasteurized pâté samples.

Pâté	Chemical component (%)		
	Moisture	Protein	Fat
P-CO	52.77±0.16[b]	11.17±0.03[c]	34.55±0.56[b]
P-20	47.47±0.16[a]	10.88±0.03[b]	39.21±0.22[a]
P40	47.35±0.16[a]	10.55±0.10[a]	39.69±0.19[a]

P-CO: control **pâté**; P-20 and P-40: **pâtés** with 20% and 40% of pork fat replacement

P-20 and P-40: samples with 20% and 40% of pork fat replacement

[a,b,c] Different letters in the column mean that **pâtés** are statistically different

Table 3. Color parameters (L^*, a^*, b^*) of pâté samples.

Pâté	L^*	a^*	b^*
P-CO	69.54±0.50[a]	10.65±0.11[a]	15.17±0.17[a]
P-20	67.85±0.39[b]	11.66±0.17[b]	15.58±0.25[b]
P40	65.87±0.50[c]	12.63±0.18[c]	16.41±0.15[c]

P-CO: control **pâté**; P-20 and P-40: **pâtés** with 20% and 40% of pork fat replacement
P-20 and P-40: samples with 20% and 40% of pork fat replacement
[a,b,c] Different letters in the column mean that **pâtés** are statistically different

Moreover, the substitution of animal fat with oleogel led to a decrease in moisture content. The lower moisture content (Table 2) observed in P-20 (47.47±0.16[a]) and P-40 (47.35±0.16[a]) compared to the control pâté P-CO (52.77±0.16[b]) could be attributed to the backfat moisture content. The pâtés with oleogels did not differ significantly (p>0.05) in terms of fat and moisture content.

The control pâté exhibited a significantly higher (p<0.05) protein content (11.17±0.02[c]) compared to the P-20 (10.88±0.03[b]) and P-40 (10.55±0.10[a]) pâtés. This difference can be attributed to the presence of approximately 9% protein in pork backfat (*Vargas-Ramella et al.*, 2020). Consequently, the partial replacement of backfat with oleogel, which lacks protein, led to a significant decrease in the overall protein content. Our findings align with previous studies conducted on pâté (*Barbut*, 2015; *Martins et al.*, 2020), further corroborating the observed trend.

According to the instrumental measurement of color, liver pâtés with the addition of oleogel were significantly (p<0.05) darker, redder, and more yellow compared to the control pâté (Table 3). These color changes can be attributed to the properties of the added oleogel, because most vegetable oils, obtained by cold pressing, are yellow or yellowish-brown, with red or green tone. The most common natural pigments in the oils are carotenoids (yellow) and chlorophylls, green color pigments (*Romanić et al.*, 2021). Also, yellow tonality is a contribution from the presence of (opaque characteristic) CW.

Analyzing the texture characteristics of the pâtés, the statistical findings allow comparison of firmness and work of shear, which in turn determine the products' spreadability (*Shakerardekani et al.*, 2013). Spreadability (work of shear) is an extremely important attribute of spreadable products, as it is related to how easy the product is uniformly distributed over a surface (*Daubert et al.*, 1998). The control pâté (P-CO), which did not contain oleogel, exhibited the highest firmness (357.88±14.37[a]) and work of shear (374.85±25.07[a]), indicating the lowest spreadability. On the other hand, the pâté with 40% substitution demonstrated significantly lower (p<0.05) firmness (213.10±16.14[c]) and work of share (201.32±32.76[b]), and thus, higher spreadability. Texture was improved since oleogel addition resulted in softer and more spreadable pâté (*Morales-Irigoyen*, 2012). According to (*Shakerardekani et al.*, 2013) the oleogel implementation resulted in a soft texture of the meat product which was preferred by consumers compared to other treatments. Consumer sensory evaluation revealed significantly higher overall liking scores (p<0.05) of meat products containing oleogel, thus indicating that the oleogel treatment enhanced the sensory quality and acceptability of

Table 4. Texture (firmness and work of shear) for P-CO, P-20 and P-40 pâté samples, as a result of texture profile analysis (TPA)

Pâté	Firmness (g)	Work of shear (g sec)
P-CO	357.88±14.37[a]	374.85±25.07[a]
P-20	300.85±10.18[b]	312.43±17.58[a]
P40	213.10±16.14[c]	201.32±32.76[b]

P-CO: control pâté; P-20 and P-40: pâtés with 20% and 40% of pork fat replacement
P-20 and P-40: samples with 20% and 40% of pork fat replacement
[a,b,c] Different letters in the column mean that pâtés are statistically different

the pâté. These findings highlight the importance of texture in consumer satisfaction and suggest that the use of oleogel incorporation can contribute to creating more desirable meat products that meet consumer preferences (*Issara et al*., 2022).

4. Conclusion

Overall, the utilization of oleogel as a substitute for animal fat in pâté formulations resulted in changes in lipid, moisture, and protein content. The incorporation of oleogel in liver pâté formulation influenced its color characteristics, making it darker, redder, and more yellow compared to the control pâté. These color changes can be attributed to the properties of the added oleogel and offer potential for tailoring the visual appearance of liver pâté products. The incorporation of oleogels in pâtés can modify their textural properties, potentially providing options to alter the spreadability and overall consumer acceptance of these products. These findings highlight the potential for modifying the composition of pâté and offer insights into the effects of incorporating oleogel in such meat-based products.

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