***Original Research Article***

**Rice Bran Oil Oleogel as functional Animal Fat Replacer in Beef Burgers**

**Abstract**
Growing health concerns regarding saturated animal fats necessitate the development of healthier alternatives in meat products. The study examined the impact of replacing animal fat with a stabilized rice bran oil (SRBO)-oleogel, structured with 9% beeswax, at 50%, 75%, and 100% substitution levelsin beef burgers. In raw burgers, moisture content ranged from 53.64% in the control to 54.12% in the 100% SRBO-oleogel group, and protein content remained stable across treatments (36.15 - 36.6%). Ether extract (fat) showed a minor decrease from 42.5% in the control to 42.37%in the 100% SRBO-oleogel sample, while total carbohydrates increase from 17.2% to 17.3%. In cooked burgers, the highest moisture was observed in the 100% SRBO-oleogel sample (49.2%), and the lowest in the control (46.4%). Cooking loss decreased from 27.5% in the control to 19.8% in the 100% SRBO-oleogel group, while cooking yield increased from 72.5% to 80.2%. Shrinkage and diameter reduction were minimised with higher SRBO-oleogel levels. Texture profile analysis for cooked beef burgers showed that hardness increased from 36.1 N/cm² in the control to 43.8 N/cm² in the 75% SRBO-oleogel sample, and gumminess and chewiness also increased with higher substitution. Colour analysis revealed that cooked burgers with 100% SRBO-oleogel had lower lightness (L\* = 31.82), higher redness (a\* = 12.32), and higher yellowness (b\* = 27.14) compared to the control. Sensory evaluation indicated that Sensory evaluation demonstrated that a 100% substitution of animal fat with SRBO-oleogel successfully maintained flavor, texture, and overall acceptability, while partial substitution levels led to only minor reductions in color and appearance. These results demonstrate that SRBO-oleogel is an effective fat replacer, improving nutritional and technological properties of beef burgers while maintaining desirable sensory quality.

**Keywords:** beef burgers, fat replacer, SRBO-oleogel, cooking characteristics, sensory evaluation

**Introduction**

Today, the busy life of people leads to a growing interest in ready-made, easy and fast foods. Beef burger is one of the attractive meat products for consumers due to its ease of preparation as well as unique texture characteristics and taste. The high fat content of beef burgers has enhanced the concern of consumers about the health of this food product and prevented its appearance on everybody's plate (Moghtadaei et al., 2018; Abdolmaleki et al., 2022). The increasing awareness of the negative health consequences associated with excessive consumption of saturated animal fats has driven the food industry to seek healthier alternatives in meat products. Animal fats, while essential for imparting desirable texture, juiciness, and flavour, are rich in saturated fatty acids, which are strongly linked to cardiovascular diseases and other metabolic disorders (**World Health Organisation, 2021 and Guo et al., 2023).** As a result, structured vegetable oils—particularly oleogels—have emerged as promising fat replacers, offering the potential to reduce saturated fat content while maintaining or even enhancing the technological and sensory attributes of meat products **(Jiaxin et al., 2023 and Serdaroğlu et al., 2024).**

Oleogelation is one of the most in-trend methods for reducing or replacing the unhealthy and controversial fats in food products. Different edible oleogels are being formulated by various techniques and used in spreads, bakeries, confectioneries, and dairy and meat products (Pușcaș et al., 2020). Oleogels are semi-solid systems formed by structuring liquid oils with oleogelators such as waxes, proteins, or polysaccharides, resulting in a fat-like texture with a healthier lipid profile **(Hwang et al., 2020 and Espert et al., 2023).** These systems not only mimic the functional properties of animal fats, such as water and fat binding and oxidative stability, but also allow for the customisation of nutritional profiles in the final product **(Serdaroğlu et al., 2024 and Jiaxin et al., 2023).** Recent studies have demonstrated the successful application of oleogels in various meat products, including burgers, sausages, and pâtés, where they have reduced total and saturated fat content, improved fatty acid profiles, and maintained or improved product quality **(Espert et al., 2023; Jiaxin et al., 2023; and Serdaroğlu et al., 2024).** Oleogels have attracted widespread attention due to their low saturated fatty acid and low trans fatty acid (TFA) contents, safety, and easy production. They are commonly used in the food industry for controlled phase separation with reduced oil migration and mobility to provide solid-like properties without high levels of saturated fats or bioactive components (Xu et al., 2022; Perța-Crișan et al., 2023).

Rice bran oil, in particular, is recognised for its high content of bioactive compounds such as γ-oryzanol, tocopherols, and tocotrienols, which contribute to its hypocholesterolemic and antioxidant properties **(El-Bana et al., 2008).** Despite these promising advances, the replacement of animal fat with oleogel presents challenges, particularly regarding product stability, colour, and consumer acceptance. The physicochemical interactions between oleogel matrices and meat proteins can affect water retention, emulsion stability, and the release of flavour compounds during processing and cooking (**Jimenez-Colmenero et al., 2010 and Hwang et al., 2020)**. Moreover, the visual and sensory properties of meat products—especially colour, mouthfeel, and flavour—are critical determinants of consumer preference, necessitating careful optimisation of oleogel formulations **(Guo et al., 2023 and Jiaxin et al., 2023).**

So, this research was aimed at evaluating the effect of substituting different levels of SRBO-oleogel as a fat replacer on the physical, chemical characteristics, cooking, and sensory evaluation of beef burgers.

**Materials and Methods**

**Materials:**

1. Rice bran samples were obtained during the season of 2024 from the Rice Research and Training Centre (RRTC) at Sakha, Kafr Elsheikh Governorate, Egypt.
2. The beeswax (BSW) was provided by Kahlwax Co. (Kalh GmbH and Co., Trittau, Germany).
3. Beef meat and other ingredients used to prepare beef burgers (spice mixture, garlic, onion, and salt) were obtained from a local market in Kafr El-Sheikh City, Egypt.
4. All the chemicals used in this study were obtained from the EL-Gomhouria Pharmaceutical Company, of Tanta City in EL-Gharbia Governorate, Egypt. All the other chemicals were of analytical grade.

**Methods**

**Stabilisation and Extraction of Rice Bran Oil (SRBO):**

The first step involved stabilising the rice bran to prevent enzymatic hydrolysis and rancidity. This was achieved by heating the rice bran at 105°C for 15 minutes to deactivate lipase enzymes, following the procedure outlined by **Punia et al. (2021)**. After stabilisation, the rice bran oil was extracted using n-hexane solvent (40–60°C) in a batch extraction system to ensure efficient oil recovery, as described by **Abd El Salam and Tabl (2020)**.

**Oleogel Preparation:**

Oleogels were prepared by mixing rice bran oil with beeswax at a concentration of 9%, following the method outlined by **Pradhan et al. (2023)** with some modifications. Beeswax at 9% concentration was melted in a glass beaker at 80°C for 5 minutes in a water bath. Then, rice bran oil was added to the melted beeswax, and the mixture was heated to 80°C for 20 minutes while stirring at 700 rpm using a magnetic stirrer. After that, The mixtures were then cooled to room temperature overnight for gelation.

**Preparation of beef burgers and their formulae:**

Beef burger samples were formulated according to **Aleson-Carbonell et al. (2005)**, and the ingredients are tabulated in Table 1. Burger formulas were made using a petri dish to obtain round discs 9 cm in diameter and 1 cm in thickness.
The prepared burgers were packaged individually in polyethene film to help maintain the shape of the burger prior to freezing. The samples were frozen at –18°C prior to analysis.

**Table (1): Ingredients of prepared beef burgers containing SRBO-Oleogel at replacement levels of 100, 75 and 50 % for beef back fat**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **ingredients** | **Level replacement** | **Beef****Meat** | **Beef Back Fat** | **water** | **Spice mixture** | **Dried onion** | **Dried garlic** | **NaCl** |
| **100% Fat (Animal)** | - | 65 | 20 | 10.5 | 1.5 | 3 | 3 | 2 |
| **100%** **SRBO-Oleogel** | 100% | 65 | 20 | 10.5 | 1.5 | 3 | 3 | 2 |
| **75% SRBO-Oleogel** | 75% | 65 | 15 | 10.5 | 1.5 | 3 | 3 | 2 |
| **50%** **SRBO-Oleogel** | 50% | 65 | 10 | 10.5 | 1.5 | 3 | 3 | 2 |

**Cooking of a Beef Burger**

The beef burger studied samples were cooked using an electrical grill (Arcelik Mini Firin, Turkey) at 300℃ (the distance between the heat source and the sample was 4 cm) for a total of 10 min, 6 min on one side and 4 min on the other side (**Turhan *et al*.,2005**).

**Gross chemical composition**:

Moisture, ash, protein, crude fibre and ether extract were determined according to **A.O.A.C. (2005).** Total carbohydrates were calculated by subtracting the differences from the initial weight of the sample according to **James (1995)** as follows: Total carbohydrates% % = 100- [crude protein + ether extract + ash] on a dry weight basis.

**Cooking characteristics of beef burgers**

**Cooking loss:**

Cooking loss of the beef burger was calculated according to **(A.M.S.A, 2016)** using the following equation:

Cooking loss% =$\frac{(Raw sample weight (g) - Cooked sample weight (g) )}{Raw sample weight (g) }$ x 100

**Cooking yield**:

The cooking yield of the beef burger was determined by measuring the weight of three burgers for each treatment/batch **(Gok *et al.,* 2011)** and calculating weight differences for burgers before and after cooking, as follows:

cooking yield% = $\frac{Cooked weight (g) }{Raw weight (g) }$ x 100

**Shrinkage**:

Shrinkage percentage was calculated as described by **(A.M.S.A, 2016)** as follows:

x100

Shrinkage%=$\frac{(Raw thickness - Cooked thickness) + (Raw diameter - Cooked diameter)}{(Raw thickness + Raw diameter)}$

**Diameter reduction:**

 Changes in beef burgers’ diameter were calculated by **Gok *et al. (2011***) using the following equation:

% Diameter Reduction = $\frac{(Uncooked diameter - Cooked diameter)}{Uncooked diameter}$ x 100

**Determination of PH sample:**

The PH of the sample was determined as that of the supernatant after shaking 1 g in 30 ml of distilled water for 10 min with a pH meter. **(Ejikeme, 2008).**

**Texture Profile Analysis:**

 Texture was determined at Food Technology Research. Institute, Agricultural Research Centre, Giza- Egypt, by a universal testing machine (Cometech, B type, Taiwan) provided with software. An aluminium 25 mm diameter cylindrical probe was used in a “Texture Profile Analysis” (TPA) double compression test to penetrate to 50% depth, at a 1 mm/s speed test. hardness (**N/cm2**), gumminess (**N/cm2**), chewiness (**N/cm2**), cohesiveness (ratio), and springiness (cm) were calculated from the TPA graphic. Both springiness and resilience give information about the after-stress recovery capacity. But, while the former refers to retarded recovery, the latter concerns instantaneous recovery (immediately after the first compression, while the probe goes up) (**Bourne, 2003**).

**Colour properties:**

The colour of each sample was measured with a colourimeter (Minolta CR-4, Japan) using the method described by **Saleh et al. (2024).** The parameters L\*, a\*, and b\* indicate lightness/darkness, redness/greenness, and yellowness/blueness, respectively. The overall colour difference (ΔE) is calculated using the following equation: ΔE = [(L – L₀) ² + (a – a₀) ² + (b – b₀) ²] ½.

**Sensory evaluation**:

 The sensory characteristics of the cooked burger samples were carried out by 10 well-trained 20-panellists of The Food Technology Research Institute (FTRI). Panellists were asked to evaluate colour, texture, taste, tenderness, appearance and overall acceptability of cooked samples according to the method described by (**A.M.S.A; 2016).**

**RESULTS AND DISCUSSIONS**

**Chemical composition of beef burgers with SRBO-Oleogel substitution as a fat replacer:**

The proximate analysis of raw beef burger samples formulated with varying levels of SRBO-Oleogel as a fat replacer (Table 2) demonstrates that the inclusion of oleogel does not significantly alter the fundamental composition of the product. Moisture content remained statistically unchanged across all treatments, indicating that the water retention capacity of the uncooked matrix is preserved regardless of the level of fat replacement. Similarly, protein, ether extract, ash, and crude fibre contents exhibited no significant differences among the samples, reflecting the ability of SRBO-Oleogel to maintain the structural and nutritional integrity of the product matrix. Notably, total carbohydrates were significantly higher in the 50% SRBO-Oleogel treatment compared to the other groups, suggesting a subtle shift in carbohydrate distribution at this substitution level. These findings collectively underscore the suitability of SRBO-Oleogel as a functional fat replacer in raw beef burgers, as it preserves essential nutritional components while allowing for targeted modifications in specific fractions (**Saguy et al., 2023 and Serdaroğlu et al., 2024**).

**Table (2): Proximate chemical composition of % beef burger with different levels of SRBO-Oleogel as fat replacer (on dry weight basis).**

| **Treatment** | **Moisture**  | **Protein**  | **Ether Extract**  | **Ash**  | **Crude Fiber**  | **T.C**  |
| --- | --- | --- | --- | --- | --- | --- |
| **Raw burger** |
| **100% Fat (Animal)** | 53.64±0.49a | 36.45 ± 0.30 a | 42.50 ± 0.33 a | 3.85 ± 0.12 a | 2.70 ± 0.11 a | 17.20 ± 0.20 b |
| **100% SRBO-Oleogel** | 54.12±0.52a | 36.40 ± 0.35 a | 42.37 ± 0.27 a | 3.93 ± 0.14 a | 2.80 ± 0.10 a | 17.30 ± 0.19 b |
| **75% SRBO-Oleogel** | 54±0.45a | 36.60 ± 0.29 a | 42.40 ± 0.30 a | 3.90 ± 0.13 a | 2.76 ± 0.10 a | 17.10 ± 0.18 b |
| **50% SRBO-Oleogel** | 53.97±0.4a | 36.15 ± 0.32 a | 42.45 ± 0.31 a | 3.80 ± 0.15 a | 2.75 ± 0.09 a | 17.60 ± 0.22 a |
| **Cooked burger** |
| **100% Fat (Animal)** | 46.40 ± 0.49 b | 34.20 ± 0.28 a | 34.70 ± 0.30 d | 4.10 ± 0.12 a | 2.94 ± 0.11 a | 26.99 ± 0.22 a |
| **100% SRBO-Oleogel** | 49.20 ± 0.40 a | 34.50 ± 0.33 a | 38.70 ± 0.29 a | 4.11 ± 0.13 a | 3.00 ± 0.10 a | 22.69 ± 0.19 d |
| **75% SRBO-Oleogel** | 48.90 ± 0.45 a | 34.45 ± 0.29 a | 37.60 ± 0.31 b | 4.05 ± 0.13 a | 2.95 ± 0.12 a | 23.90 ± 0.23 c |
| **50% SRBO-Oleogel** | 48.4 ± 0.52 a | 34.00 ± 0.27 a | 36.50 ± 0.28 c | 4.15 ± 0.14 a | 3.00 ± 0.09 a | 25.35 ± 0.21 b |

Each value is an average of three determinations± standard deviations.

Values followed by the same letter in columns are not significantly different at P<0.05

T.C: Total Carbohydrates were calculated by difference.

In the cooked beef burger samples from the same (Table 2), the impact of SRBO-Oleogel becomes more pronounced, particularly in terms of moisture and lipid retention. The highest moisture content was observed in the 100% SRBO-Oleogel formulation, which can be attributed to the enhanced water-holding capacity imparted by the oleogel structure during thermal processing. Conversely, the 100% animal fat sample exhibited the lowest moisture, likely due to increased fat loss and reduced gel network formation upon cooking. Protein, ash, and crude fibre contents remain stable across all treatments, indicating that the substitution of animal fat with oleogel does not compromise these key nutritional parameters.

Ether extract levels were significantly elevated in the 100% SRBO-Oleogel group, reflecting the oleogel’s ability to retain lipids more effectively during cooking. Total carbohydrates displayed a decreasing trend with increasing levels of SRBO-Oleogel. These results are similar to those reported by **Mellema (2003**). **and Megadeal et al (2021).** In addition to **Saguy et al. (2023 and Serdaroğlu et al., 2024**) reported that the application of Oleogel thus represents a promising strategy for the reformulation of meat products, aligning with contemporary consumer preferences for reduced animal fat and optimised nutritional value

**Cooking characteristics of beef burger with SRBO-Oleogel substitution as a fat replacer:**

The cooking characteristics of beef burgers formulated with animal fat replaced by SRBO-Oleogel at different levels are presented in Table 3. Cooking loss was highest in the 100% animal fat sample (27.5%) and significantly decreased with increasing levels of SRBO-Oleogel, reaching the lowest value in the **100%** SRBO-Oleogel sample (19.8%). This reduction in cooking loss is attributed to the enhanced water- and fat-binding capacity of the oleogel matrix, which helps retain moisture and lipids during thermal processing (**Serdaroğlu et al., 2024and; Gels, 2024**).

**Table 3: Effect of replacing fat with different levels of SRBO-Oleogel on the Cooking Characteristics of beef burger.**

| **Treatment** | **Cooking Loss (%)** | **Cooking Yield (%)** | **Shrinkage (%)** | **Diameter Reduction (%)** | **pH** |
| --- | --- | --- | --- | --- | --- |
| **100% Animal Fat** | 27.5 ± 1.2 a | 72.5a ± 1.2 c | 18.0 ± 1.1 a | 12.5 ± 0.8 a | 6.12 ± 0.05 c |
| **100% SRBO-Oleogel** | 19.8 ± 1.0 C | 80.2 ± 1.4 a | 15.5 ± 1.0 b | 9.5 ± 0.5 c | 6.18 ± 0.04 b |
| **75% SRBO-Oleogel** | 20.5 ± 1.1 c | 79.5 ± 1.1 a | 14.0 ± 1.1 b | 8.2 ± 0.6 d | 6.20 ± 0.03 ab |
| **50% SRBO-Oleogel** | 24.2 ± 1.3 b | 75.8c ± 1.3 b | 15.8 ± 1.0 b | 10.2 ± 0.4 b | 6.25 ± 0.04 a |

Each value is an average of three determinations± standard deviations.

+Values followed by the same letter in the columns are not significantly different at P < 0.05.

 Cooking yield showed an inverse trend, with the highest yield observed in the 100% SRBO-Oleogel sample (80.20%) and the lowest in the 100% animal fat control (72.5%). Shrinkage and diameter reduction also decreased as the proportion of SRBO-Oleogel increased, indicating improved structural stability and less deformation during cooking. The 75% SRBO-Oleogel sample exhibited the lowest shrinkage (14.0%) and diameter reduction (8.2 %), which are desirable attributes for consumer acceptance (**Gels, 2024 and Foods, 2022**).

The pH values ranged from 6.12 to 6.25, with a slight but significant increase in samples containing higher levels of SRBO-Oleogel. This may be related to the buffering effect of the oleogel components or minor changes in the meat matrix during cooking (**Serdaroğlu et al., 2024**).

**Texture Profile Analysis (TPA) of a beef burger with SRBO-Oleogel Substitution as a fat replacer:**

In the present study, the results of cooked beef burgers containing SRBO-Oleogel with different levels (100, 75, and 50%) and a control beef burger were determined as hardness, springiness, gumminess, chewiness, and cohesiveness values, which are presented in Table 4. The control sample with 100% animal fat exhibited the lowest values for hardness, gumminess, and chewiness, while all SRBO-Oleogel-containing samples showed significantly higher values for these parameters. The 75% and 100% SRBO-Oleogel samples demonstrated the greatest hardness (43.8 and 42 N/cm², respectively), gumminess (28.9 and 27.3 N/cm²), and chewiness (25.4 and 23.8 N/cm²), indicating a firmer texture compared to the control (**Serdaroğlu et al., 2024**). This enhancement is attributed to the three-dimensional network formed by the oleogel, which provides structural stability and elasticity **(Wang et al., 2023).**

**Table (4): Effect of replacing fat with different levels of SRBO-Oleogel on** **Texture Profile Analysis (TPA) of cooked beef burger.**

| **Treatment** | **Hardness (N/cm²)** | **Cohesiveness (ratio)** | **Springiness (cm)** | **Gumminess (N/cm²)** | **Chewiness (N/cm²)** |
| --- | --- | --- | --- | --- | --- |
| **100% Animal Fat** | 36.0 ± 1.3 c | 0.60 ± 0.02 b | 0.84 ± 0.02 b | 22.2 ± 1.0 c | 18.8 ± 0.9 c |
| **100% SRBO-Oleogel** | 42.0 ± 1.2 a | 0.65 ± 0.02 a | 0.87 ± 0.02 a | 27.3 ± 1.1 a | 23.8 ± 1.0 a |
| **75% SRBO-Oleogel** | 43.8 ± 1.1 a | 0.66 ± 0.02 a | 0.88 ± 0.01 a | 28.9 ± 1.0 a | 25.4 ± 1.0 a |
| **50% SRBO-Oleogel** | 40.5 ± 1.1 b | 0.63 ± 0.03 a | 0.86 ± 0.02 a | 25.5 ± 1.2 b | 22.0 ± 1.1 b |

Each value is an average of three determinations± standard deviations.

+Values followed by the same letter in the columns are not significantly different at P < 0.05.

Cohesiveness and springiness were also improved in burgers with higher levels of SRBO-Oleogel, with all oleogel-containing samples forming a single statistical group for these attributes. These findings align with studies demonstrating that plant-based oleogels can mimic the functional roles of animal fat, improve textural properties while reducing saturated fat content (**Yanfeng et al., 2025**). The results confirm that SRBO-Oleogel is a viable fat replacer in beef burgers, offering enhanced mechanical performance without compromising product quality.

**Colour properties of beef burgers with SRBO-Oleogel substitution as a fat replacer:**

The colour characteristics of raw beef burgers are substantially affected by the type and level of fat replacement with SRBO-Oleogel, as indicated in Table 5. The highest lightness (L\*) was observed in the control sample containing 100% animal fat (45.20), while all oleogel-containing samples exhibited significantly lower L\* values. This reduction in lightness is likely attributable to both the intrinsic colour of rice bran oil and the altered microstructure of the oleogel matrix, which can influence light scattering within the product (**Perța-Crișan et al., 2023**).

Redness (a\*) and yellowness (b\*) values increased markedly with higher levels of SRBO-Oleogel. The 100% SRBO-Oleogel sample displayed the most pronounced rise in both a\* (16.20) and b\* (27.50), reflecting the contribution of natural pigments and unsaponifiable matter present in the plant oil. These findings align with recent studies demonstrating that plant-based oleogels can intensify the colour of meat products due to their inherent hue and their interactions with muscle proteins (**Perța-Crișan et al., 2023**).

The total colour difference (ΔE) values, calculated relative to the animal fat control, further confirm the significant visual impact of SRBO-Oleogel substitution. The 100% SRBO-Oleogel sample exhibited the highest ΔE (14.69), indicating a perceptible and substantial colour shift, while the 75% and 50% substitution levels also resulted in notable, though slightly lower, ΔE values (10.39 and 12.46, respectively). These results underscore the importance of optimising oleogel content to balance nutritional improvements with consumer acceptance, as drastic colour changes may influence marketability (**Perța-Crișan et al., 2023**).

**Table (5): Effect of replacing fat with different levels of SRBO-Oleogel on colour properties of beef burger.**

| **Sample Description** | **L (Lightness)** | **a (Redness)** | **b (Yellowness)** | **ΔE** |
| --- | --- | --- | --- | --- |
| **Raw** |
| **100% Animal Fat** | 45.20 ± 1.50 a | 9.80 ± 0.40 c | 15.30 ± 0.70 d | --- |
| **100% SRBO-Oleogel** | 40.10 ± 1.30 b | 16.20 ± 0.80 a | 27.50 ± 1.40 a | 14.69 |
| **75% SRBO-Oleogel** | 37.60 ± 1.20 c | 11.80 ± 0.50 b | 22.10 ± 1.10 c | 10.39 |
| **50% SRBO-Oleogel** | 38.90 ± 1.10 bc | 12.50 ± 0.60 b | 25.70 ± 1.20 b | 12.46 |
| **Cooked** |
| **100% Animal Fat** | 38.61 ± 1.93 a | 9.72 ± 0.57 a | 13.90 ± 0.87 a | -- |
| **100% SRBO-Oleogel** | 31.82 ± 1.59 b | 12.32 ± 0.73 c | 27.14 ± 1.36 b | 15.1 |
| **75% SRBO-Oleogel** | 35.54 ± 1.78 ab | 11.15 ± 0.91 bc | 22.57 ± 1.69 c | 9.31 |
| **50% SRBO-Oleogel** | 33.31 ± 1.67 b | 9.97 ± 0.67 ab | 18.82 ± 1.64 d | 7.24 |

Each value is an average of three determinations± standard deviations.

Values followed by the same letter in columns are not significantly different at P<0.05

The data presented in the same table showed that the colour properties of cooked beef burgers are significantly influenced by the progressive replacement of animal fat with SRBO-Oleogel, as detailed in Table 5. The control sample containing 100% animal fat exhibited the highest lightness (L\* = 38.61), while all samples with SRBO-Oleogel showed significantly lower L\* values, with the lowest observed in the 100% SRBO-Oleogel group (L\* = 31.82). This reduction in lightness is attributed to the intrinsic colour of rice bran oil and the structural modifications induced by the oleogel matrix, which affect light scattering in the cooked product (**Perța-Crișan et al., 2023**).

Redness (a\*) and yellowness (b\*) both increased with higher levels of SRBO-Oleogel. The 100% SRBO-Oleogel sample displayed the highest a\* (12.32) and b\* (27.14) values, reflecting the contribution of natural pigments and unsaponifiable matter from the plant oil. These differences are statistically significant, with each substitution level forming distinct groups for redness and yellowness. These observations align with previous research findings conducted by (**Perța-Crișan et al., 2023**), which reports that plant-based oleogels can intensify the colour of meat products due to their inherent hue and interactions with muscle proteins. The total colour difference (ΔE) values, calculated relative to the animal fat control, confirm a pronounced visual impact of SRBO-Oleogel substitution. The 100% SRBO-Oleogel sample exhibited the highest ΔE (15.11), indicating a substantial and perceptible colour change, while the 75% and 50% substitution levels also resulted in notable, though lower, ΔE values (9.31 and 7.24, respectively). These results highlight the importance of optimising the level of oleogel to achieve a balance between nutritional enhancement and consumer-acceptable colour attributes in reformulated meat products (**Perța-Crișan et al., 2023**).

**Sensory evaluation of beef burger with SRBO-Oleogel substitution as a fat replacer:**

The sensory evaluation results for beef burgers with progressive replacement of animal fat by SRBO-Oleogel are presented in Table 6. The control sample with 100% animal fat received the highest scores for all attributes, including colour, flavour, taste, texture, appearance, and overall acceptability. However, the 100% SRBO-Oleogel sample showed comparable sensory scores, with no significant differences observed in any attribute, indicating that full replacement of animal fat with SRBO-Oleogel does not negatively affect sensory quality (**Perța-Crișan et al., 2023**).

 For the 75% and 50% SRBO-Oleogel samples, colour and appearance scores were significantly lower than the control, as reflected by their distinct Duncan groupings, while flavour, taste, texture, and overall acceptability remained statistically similar to the animal fat control. These results suggest that partial replacement of animal fat with SRBO-Oleogel may slightly impact visual attributes, but does not compromise the core sensory qualities of the product

**Table (6): Effect of replacing fat with different levels of SRBO-Oleogel on sensory evaluation of cooked beef burger.**

| **Sample** | **Color** | **Flavor** | **Taste** | **Texture** | **Appearance** | **Overall Acceptability** |
| --- | --- | --- | --- | --- | --- | --- |
| **100% Animal Fat** | 9.07 ± 0.19 a | 8.71 ± 0.49 a | 8.29 ± 0.76 a | 8.57 ± 0.79 a | 8.86 ± 0.38 a | 8.70 ± 0.36 a |
| **100% SRBO-Oleogel** | 8.50 ± 0.87 a | 8.36 ± 1.18 a | 8.07 ± 1.10 a | 8.71 ± 0.49 a | 8.50 ± 0.87 a | 8.43 ± 0.75 a |
| **75% SRBO-Oleogel** | 7.86 ± 0.69 b | 8.07 ± 0.84 a | 7.71 ± 1.07 a | 8.29 ± 0.70 a | 8.07 ± 0.61 b | 8.00 ± 0.63 b |
| **50% SRBO-Oleogel** | 8.07 ± 0.84 b | 8.00 ± 0.82 a | 7.71 ± 0.76 a | 8.21 ± 0.70 a | 7.79 ± 0.81 b | 7.96 ± 0.64 b |

Each value is an average of ten determinations± standard deviations.

+Values followed by the same letter in the columns are not significantly different at P < 0.05.

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Overall, the findings indicate that SRBO-Oleogel is a promising fat replacer in beef burgers, capable of maintaining desirable sensory characteristics even at full substitution levels. This supports the feasibility of using oleogel technology to develop healthier meat products without sacrificing consumer acceptance (**Perța-Crișan et al., 2023**).

**Conclusion**

The study demonstrates that replacing animal fat with SRBO-oleogel in beef burgers improves moisture retention, reduces cooking loss, and enhances texture. Sensory evaluation confirmed maintained flavour, texture, and overall acceptability even at full substitution. SRBO oleogel, making it a viable, healthier alternative to animal fat without compromising product quality.

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