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Tailor-made chicken meat biscuits: optimizing functional properties with olive oil and flaxseed oil oleogels

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ABSTRACT

This study aimed to develop chicken meat biscuits incorporating oleogels derived from olive oil and flaxseed oil, using carnauba wax as the oleogelator. The objectives included standardizing the procedure for preparing chicken meat biscuits, developing oleogels, and evaluating the physico-chemical, microbiological, and sensory quality of the resulting products, along with determining shelf life. Chicken meat biscuits were formulated with commercial butter (C), olive oil oleogel (T1), and flaxseed oil oleogel (T2). Physico-chemical parameters, fatty acid profile, and sensory quality were analyzed. Stable oleogels were obtained, and chicken meat biscuits incorporated with flaxseed oil oleogel exhibited reduced hardness, increased baking yield and maintained proximate composition. Fatty acid profiling revealed a significant decrease in saturated fatty acids in T2, with an increased PUFA: SFA ratio and favorable health indices. Sensory evaluation indicated no significant differences among formulations. Shelf-life assessment under ambient and refrigerated conditions showed T2's superior performance in terms of pH, lipid peroxidation, microbial quality, and sensory acceptability over 45 days of storage. The findings suggest that these innovative biscuits have promising applications in the food industry, providing healthier alternatives without compromising taste and texture.
Key words: Oleogels; Omega fatty acids; Fortification; Chicken meat biscuit; Fatty acid profile.

INTRODUCTION

Meat serves as an excellent protein source and is rich in essential vitamins (especially B12) and minerals such as iodine, zinc, and iron, alongside essential fatty acids. The demand for ready-to-eat (RTE) products has surged recently. The global market for RTE meat products is projected to grow at a compound annual growth rate (CAGR) of 4.8% until 2026, according to a report by Straits Research (https://straitsresearch.com/report/ready-to-eat-meat-products-market/). Despite potential threats to the market growth of RTE meat products like microbial contamination and reduced shelf life, alternatives like cookies or biscuits present a viable option to maintain nutritional content. These snacks, which undergo chemical leavening, provide a diverse range of attributes, including adaptability, a wide variety of flavours, and a shelf life that is notably extended (Akubor & Ukwuru 2005). These snacks offer a taste experience that can suit a broad audience.

Additionally, their extended shelf life enhances convenience and makes them a practical choice for those seeking long-lasting and flavourful snack options. While these biscuits are primarily made from cereals and may lack certain amino acids, enhancing their nutritional content with animal proteins can improve the amino acid composition, flavour, odour, and taste (Kumar et al., 2016).

The significance of omega-3 fatty acids in the food industry is growing due to their health benefits, particularly in reducing the risk of cardiovascular diseases. Olive oil, extracted from olives, is rich in monounsaturated fatty acids (MUFA) and has been linked to various health benefits, including cholesterol regulation and antioxidant properties (Fito et al., 2000). Flaxseed oil, derived from the flax plant, stands out as a potent source of omega-3 fatty acids (Gebauer et al., 2006). Despite its natural antioxidant content, traditional flaxseed oil faces challenges related to oxidation after extraction (Stearns et al., 1993).

Solid edible fats, commonly used as shortenings in baked goods, improve product quality but are a health concern due to the presence of trans and saturated fatty acids. Recent nutritional guidelines emphasize reducing dietary saturated and trans fats, favouring replacement with unsaturated sources (Stortz *et al*., 2012). Efforts to replace trans and saturated fats with vegetable oils have encountered challenges such as handling issues and reduced palatability. Structuring unsaturated oils through oleogelation is a critical process, converting liquid oils into solid fats with improved stability (Mert and Demirkesen 2016). Various substances, including crystalline structures, natural waxes, and self-assembled structures can induce gelation (Blake and Marangoni 2015, Bot and Agterof 2006, Mallia and Weiss 2014). Waxes like rice bran wax, sunflower wax, candelilla wax, carnauba wax, and beeswax have gained attention for their applications in food. Carnauba wax, extracted from the leaves of the Brazilian palm, holds economic importance and diverse chemical composition (Lorenzi *et al*., 2010). It has a high melting point, less viscosity, and elastic properties, making it widely used in foods with authorization from regulatory bodies (Doan et al., 2018).

The study aims to develop chicken meat biscuits/cookies with olive oil and flaxseed oil oleogels using carnauba wax as the oleogelator. The objectives include standardizing the procedure for preparing chicken meat biscuits, developing oleogels, and assessing the physico-chemical, microbiological, and sensory quality of the resulting products, along with determining shelf life.

MATERIALS AND METHODS

In this current investigation, the goal was to enhance the preparation of chicken meat biscuits (CMB) and integrate them with oleogels derived from olive oil and flaxseed oil to serve as replacements for saturated fats. The study was carried out at the Department of Livestock Products Technology, N.T.R College of Veterinary Sciences, Gannavaram.

In the initial phase, chicken meat biscuits were developed with precision, utilising a sophisticated approach to formulate oleogels with olive oil and flaxseed oil each structured with carnauba wax. The quality of the fortified biscuits and the efficacy of oleogels in replacing saturated fat were assessed through various analyses.

In the subsequent phase, chicken meat biscuits fortified with high-quality oleogel were chosen and stored at both ambient (28±1°C) and refrigerated (4±1°C) conditions. Quality evaluations were conducted at regular eight-day intervals for both ambient and refrigerated storage.

Raw Materials

Scientifically reared six-week-old broiler chickens were obtained from a local farm. The deboned chicken meat used underwent meticulous preparation, including the removal of skin, subcutaneous fat, and connective tissue. Essential ingredients, such as refined wheat flour, corn flour, baking powder, sugar, salt, butter, egg albumen, corn syrup, and spices, were sourced from the local market in Gannavaram. Chemicals and media for analysis were procured from Himedia Laboratories Pvt. Ltd, Mumbai. Olive oil, flaxseed oil, and carnauba wax were obtained from Anamaya Impex, Keshav Argo Industries, and Ibbani Fresh & Pure Pvt Ltd, respectively.

Preparation and evaluation of oleogels

Oleogels were prepared following Ogutcu and Yilmaz's (2014) method with minor adjustments, combining 95% (w/v) each of olive oil and flaxseed oil with 5% (w/v) carnauba wax. The process involved heating carnauba wax to 70°C, stirring continuously at 400 rpm, and gradually adding olive oil or flaxseed oil according to the oleogel to be formed. After solidification at room temperature, the gels were chilled at 3°C for future use. Visual inspection assessed their firm structure and color as visualised in Fig 1 and Fig 2. Oil Binding Capacity (OBC) was determined by centrifuging a 5g sample at 10,000 rpm for 15 minutes, measuring separated oil, and calculating the OBC as per the method suggested by Mashhadi et al (2023).

$$\text{Per cent oil release} = \frac{\text{Mass of expressed oil (g)}}{\text{Total mass of sample}} \times 100$$

Preparation of chicken meat biscuits with formed oleogels

Three novel chicken meat biscuit formulations were developed to investigate the impact of different oleogel types on the products sensory and textural properties. Commercial butter (C) served as the control formulation, representing a commonly used ingredient in biscuits formulations. Olive oil oleogel incorporation (T_1) introduced a healthier alternative with potential antioxidant and anti-inflammatory properties. Flaxseed oil oleogel incorporation (T_2) explored the utilization of a rich source of omega-3 fatty acids, known for their cardiovascular benefits. The level of oleogel used replaced butter entirely and was equivalent to the incorporation of shortening. The biscuits were prepared by pressure-cooking fresh boneless chicken meat followed by drying, powdering, and blending the powder with other ingredients as outlined in Table 1. The dough was then shaped into biscuits, baked until golden brown at 180°C for 40 minutes, cooled to room temperature and stored in air tight containers for subsequent evaluation. The biscuits prepared were illustrated in Fig 3, Fig 4 and Fig 5. The efficacy of oleogels in replacing shortening was assessed by analysing the following parameters.

Fig. 2: Flaxseed oil oleogel

Dimensional properties

The dimensions of the cookies were measured using the AACC-approved method (10e54, AACC, 2000) to determine their thickness, width, and spread ratio. Thickness (T) of baked cookies was determined by stacking six cookies and averaging measurements with a vernier calliper in millimetres. Diameter (W) was measured by aligning six cookies edge-to-edge, rotating the set by 90 degrees, and reporting the average values in millimetres. The spread ratio was calculated by dividing the diameter (W) by the thickness (T).

Physico-chemical Characteristics

Baking yield was calculated as the percentage of the weight of baked biscuits to the weight of raw, unbaked biscuits. Biscuit hardness was assessed using a TA-XT plus texture analyzer with a three-point bending probe, recording peak force as breakage force, according to Singh et al.'s (2015) method. Fatty acid profiling was conducted through trans-esterification and gas chromatography with flame ionization detection following the method of Dominguez et al., (2017). Various ratios and indices were calculated for nutritional insights based on the fatty acid profile. Moisture, crude protein, and crude fat percentages were estimated according to AOAC, 1995.

Fig. 3: CMB with butter

Fig. 4: CMB with Olive oil oleogel

Table 1: Composition of oleogel incorporated chicken meat biscuits

Ingredients (%)	Control (C)	T_1 (Olive oil oleogel)	T_2 (Flaxseed oil oleogel)
Meat	70.00	70.00	70.00
Shortening	5.40	5.40	5.40
Refined wheat flour	15.54	15.54	15.54
Sugar	6.20	6.20	6.20
Corn flour	1.00	1.00	1.00
Baking powder	0.30	0.30	0.30
Salt	0.20	0.20	0.20
Spice mix	0.20	0.20	0.20
Egg albumen	1.16	1.16	1.16
Total	**100**	**100**	**100**

C- Chicken meat biscuits with butter; T_1 – Chicken meat biscuits with olive oil oleogel; T_2 – Chicken meat biscuits with flaxseed oil oleogel

The biscuits incorporated with best oleogel were subjected to shelf life studies to evaluate their quality in terms of pH, lipid peroxidation, microbial counts and sensorial characteristics at regular periodic intervals of 8 days under both ambient and refrigerated storage temperatures. pH measurement utilized a digital pH meter following Trout et al.'s (1992) procedure, involving homogenizing five grams of the sample with 45 ml of distilled water. To determine the TBARS value, a modified version of Witte et al.'s (1970) extraction procedure was used. Ten grams of the sample was triturated with 25 ml of pre-cooled 20% Trichloro-acetic acid (TCA) in 2M ortho-phosphoric acid. The resulting extract was mixed, filtered, and combined with 2-thiobarbituric acid (TBA) reagent. After heating, absorbance was measured at 532 nm using a UV-VIS spectrophotometer, and the TBARS value was calculated using the formula.

TBARS value (mg of malondialdehyde per kg of sample) = OD×5.2

Microbial Quality

Microbial quality was assessed through Total Plate Count (TPC) and Yeast and Mould Counts (YMC) using the pour plate technique according to ICMSF (1980) standards. A representative sample (5 grams) was homogenized with 45 ml of 0.1 percent sterile peptone water, and ten-fold serial dilutions were prepared. Inoculated plates were incubated, and colonies were counted. Results were presented as log colony-forming units (cfu) per gram. Yeast and mould counts were determined using the pour plate technique on Potato Dextrose Agar (PDA). Colonies were counted, and results were expressed as log cfu per gram.

Sensory Evaluation

Chicken meat biscuits, prepared as per formulations, underwent sensory evaluation by a 6-member semi-trained taste panel. Appearance, flavour, crispiness, and overall acceptability were assessed on a 9-point hedonic scale.

Statistical analysis

Statistical analysis was done using SPSS MAC, version 20.0, SPSS Chicago (US).

RESULTS & DISCUSSION

Stable gels were observed upon visual examination of oleogels, characterized by the presence of small crystals without needle-like structures or dendritic formations. Both olive oil and flaxseed oil oleogels exhibited a uniform gel structure. High oil binding capacity was evident in both oleogels, with no expressed oil in the centrifuge tubes.

Dimensional and textural properties

The study meticulously assessed several key parameters, including thickness, diameter, spread ratio, and hardness values of chicken meat biscuits in both control and treatment formulations, as outlined in Table 2. Notably, the analysis revealed that thickness and diameter exhibited no significant variations between the treatment groups and the control, indicative of comparable textural attributes. The spread ratio findings suggested that the employed oleogels demonstrated a remarkable similarity to commercial butter, underscoring their efficacy in enhancing texture. The outcomes of the investigation harmonized with prior research involving diverse oils and oleogels in the context of cookies and sausages, as reported by Hwang et al. (2016), Meena et al. (2018), and Zhao et al. (2020).

Particularly noteworthy were the hardness values, which exhibited a substantial reduction in the treatment containing flaxseed oil oleogel in comparison to both the control group and the formulation incorporating olive oil oleogel. This decline in hardness can be attributed to the distinctive interaction of flaxseed oil oleogel, potentially influencing the structural composition of fats and the moisture retention capabilities of the biscuits. In contrast, the formulation with olive oil oleogel demonstrated no significant difference in hardness compared to the control, aligning with findings from other studies exploring various oils and oleogels, including those by Jang et al. (2015), Yilmaz and Ogutcu (2015), Mert and Demirksen (2016), and Kong et al. (2023). This consistency underscores the robustness of the results and contributes to the broader understanding of the intricate dynamics between different oils, oleogels, and the textural properties of food products.

Physico-chemical characteristics

The effects of incorporating oleogel on physicochemical properties are detailed in Table 2. Treatment formulations (T_1 and T_2) exhibited significantly higher baking yields compared to the control (C) formulation and no significant differences were noticed between the treatments. The incorporation of PUFA-rich oils, facilitated by the superior oil binding capacity of the utilized oleogels, led to the formation of a crystalline phase. This crystalline phase established a strong network capable of retaining liquid oil within a gel-like structure.

Consequently, this contributed to increased baking yields in the treatment formulations and the effective preservation by the oleogels during baking resulted in softer and moisture cookies. The study's findings aligned with similar outcomes in dry ripened venison sausages (Utrilla et al., 2014), chicken meat sausages (Shilpa et al., 2021), and fermented pork sausages (Zampouni et al., 2022) in previous research.

The proximate composition of all formulations in terms of percent moisture, percent crude protein, and percent crude fat were non-significantly different from each other. The consistent moisture content of chicken meat biscuits could be attributed to the uniform amount of added water during processing. Despite variations in the type of fat used, the levels of fat and the quantity of the protein source remained consistent across all formulations which could be the reason for non-significant differences in crude protein and crude fat content. These results were consistent with previous studies involving chicken meat sausages (Shilpa et al., 2021) and luncheon meat with linseed oil oleogel (Ma et al., 2023).

Fatty acid profile

The fatty acid composition of chicken meat biscuits as impacted by the inclusion of oleogels is elaborated in Table 3, Fig 6, Fig 7 and Fig 8. Control and treatment formu-

Table 2: Dimensional and Physico-chemical properties of oleogel incorporated chicken meat biscuits

Parameter	Control	Treatment-1	Treatment-2
Baking Yield (%)	80.09±1.76^a	83.62±0.89^b	83.68±1.53^b
Thickness (mm)	14.65±0.09^a	14.23±0.12^a	14.22±0.85^a
Diameter (mm)	57.55±1.05^a	57.42±0.45^a	56.25±1.02^a
Spread ratio	4.09±0.08^a	3.54±0.11^a	4.04±0.31^a
Hardness (N)	32.64±1.73^a	30.73±1.14^a	23.98±1.89^b
pH	6.39±0.02^a	6.24±0.03^b	6.16±0.06^b
Moisture (%)	10.99±0.43^a	12.02±0.43^a	12.17±0.67^a
Crude protein (%)	21.47±0.26^a	21.61±0.32^a	21.59±0.43^a
Crude fat (%)	14.46±0.45^a	14.26±0.44^a	14.12±0.33^a

• Note: Means holding common superscript in each row do not differ significantly.
• Significance: P<0.05

Table 3: Fatty acid profile of chicken meat biscuits fortified with ω-fatty acid rich oleogels

Fatty Acid	Control	Treatment-1	Treatment-2
C14:0 Myristic acid	12.00±0.54^a	1.468±0.003^b	0.000
C14:1 Myristoleic acid	1.08±0.07^a	0.294±0.01^b	0.000
C15:0 Pentadecanoic acid	1.16±0.06^a	34.789±0.78^b	0.000
C16:0 Palmitic acid	31.77±1.29^a	6.914±0.46^b	8.491±0.22^b
C16:1 Palmitoleic Acid	1.72±0.08^a	4.542±0.29^b	0.000
C17:0 Heptadecanoic acid	0.50±0.05^a	0.192±0.02^b	0.000
C18:0 Stearic acid	10.11±0.53^a	1.643±0.22^b	7.021±0.16^c
C18:1n9c Oleic acid	17.75±3.27^a	36.969±0.67^b	27.926±0.28^c
C18:2n6c Linoleic acid	1.49±0.14^a	4.828±0.32^b	12.66±0.53^c
C18:3n3 Alpha- Linolenic acid	0.43±0.09^a	0.00^a	43.214±0.38^b
C20:0 Arachidic acid	0.10±0.06^a	0.186±0.02^a	0.362±0.02^b
C20:1n9 Eicosaenoic acid	0.04±0.01^a	0.546±0.03^b	0.000
C20:2n6 Eicosadienoic acid	0.01±0.00^a	0.00^a	0.169±0.01^b
C22:2n6 Docosadienoic acid	0.03±0.01^a	0.00^a	0.157±0.02^b
PUFA/SFA	0.04±0.01^a	0.11±0.03^a	3.54±0.19^b
ω6/ω3	3.56±0.19^a	0.00^b	0.3±0.11^b
h/H	0.046±0.01^a	4.99±0.06^b	9.87±0.22^c
AI	3.54±0.12^a	0.15±0.03^b	0.1±0.02^b

• Note: Means holding common superscript in each row do not differ significantly. (Significance - P<0.05)

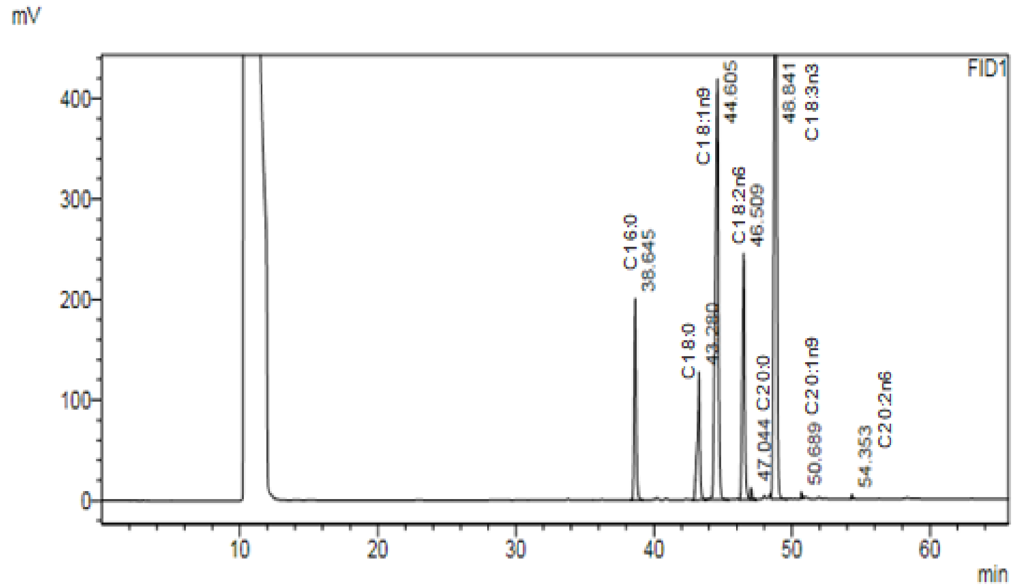

Fig. 6: Chromatogram visualizing fatty acid profile of flaxseed oil oleogel incorporated chicken meat biscuits

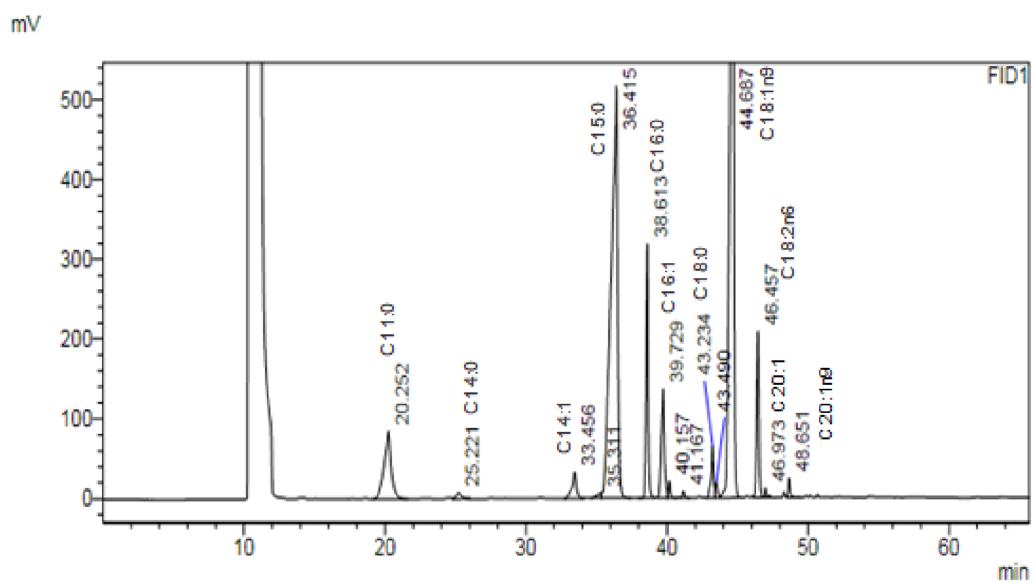

Fig. 7: Chromatogram visualizing fatty acid profile of flaxseed oil oleogel incorporated chicken meat biscuits

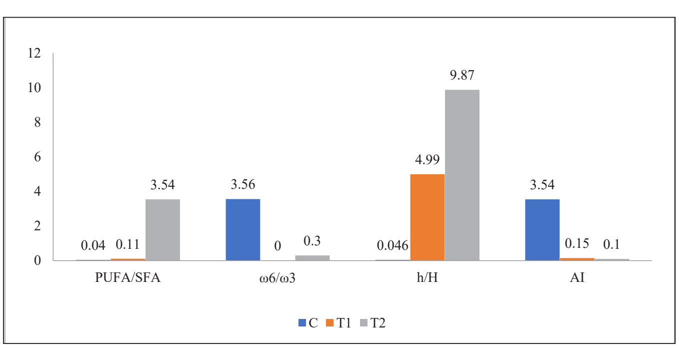

Fig. 8: Ratios related to fatty acid profile of chicken meat biscuits

lations, which included butter, olive oil, and flaxseed oil oleogels, had saturated fatty acid contents of 55.64, 45.18, and 15.87 respectively. The treatment formulations incorporated with oleogels of olive oil and flaxseed oil exhibited significantly lower saturated fatty acid content than the control.

The introduction of flaxseed oil oleogel resulted in a significant alteration of the fatty acid composition in chicken meat biscuits. The flaxseed oil oleogel formulation exhibited a favourable fatty acid profile, with 56.2% polyunsaturated fatty acids (PUFA) and 27.93% monounsaturated fatty acids (MUFA). Analysis of individual fatty acids showed that the T_2 formulation, with flaxseed oil oleogel, was rich in Alpha-linolenic acid (ALA), followed by Oleic acid and Linoleic acid. Flaxseed oil oleogel incorporation

substantially elevated PUFA content, with Alpha-linolenic acid increasing from 0.43% to 43.21%, and Linoleic acid rising from 1.49% to 12.66%. Substituting butter with flaxseed oil oleogel notably reduced saturated fatty acid content from 55.64% to 15.87%, particularly in Myristic acid, Pentadecanoic acid, Palmitic acid, Heptadecanoic acid, Stearic acid, and Arachidic acid contents. The olive oil oleogel formulation had lower PUFA (4.828%) and higher MUFA (42.351%) contents. The replacement of butter with oleogels significantly impacted MUFA content, particularly in the case of olive oil oleogel, resulting in increased MUFA to 42.35% in T_1 and 27.93% in T_2 formulations.

The T_2 formulation demonstrated a higher PUFA: SFA ratio, attributed to the greater proportion of polyunsaturated fatty acids, particularly omega-3 fatty acids from flaxseed oil, effectively replacing saturated fatty acids without compromising palatability. Consequently, the PUFA: SFA ratio increased as a positive health indicator.

The h/H index and atherogenic index (AI) for oleogel-incorporated formulations showed favourable alignment compared to the control. Notably, the T_2 formulation exhibited the highest h/H and lowest AI, indicating advantageous health effects and heart-healthy properties. These findings align with previous research, such as Zetzl et al. (2012) on frankfurters with flaxseed oil oleogel, Ozer and Celeğen (2021) on fat-reduced beef burgers with olive oil oleogel, Shilpa et al. (2021) on chicken sausages with flaxseed oil oleogel, Lopes et al. (2022) on burgers with olive oil oleogel, and Ma et al. (2023) on luncheon meat with linseed oil oleogel.

Sensory quality

The graphical representation in Figure 9 explains the impact of replacing saturated fat with oleogels derived from olive oil and flaxseed oil into chicken meat biscuits, shedding light on the detailed sensory characteristics. Meticulous examination of the data revealed an absence of any significant difference (P>0.05) in the sensory quality among all formulations. This implies a harmonious and consistent taste experience across variations, irrespective of oleogel incorporation.

This favourable outcome emphasizes the primary objective of incorporating liquid oil into the functional product through structuring, without compromising on the essential aspect of taste. The successful maintenance of the sensory characteristics, including factors like mouth feel, flavour, and texture, by oleogels highlights their success in maintaining the overall quality of the product. These findings resonate with parallel studies conducted on chicken meat sausages, as elucidated by Shilpa et al. (2021).

Due to the advantages like superior baking yield, lower moisture and crude fat content, and favourable palatability scores along with lower saturated fatty acids and higher PUFA values, leading to an increased PUFA: SFA ratio, higher h/H values and the lowest atherogenic index, the T_2 formulation was selected for shelf-life assessment, with evaluations conducted at regular intervals under ambient and refrigerated temperatures over extended periods, using airtight packaging.

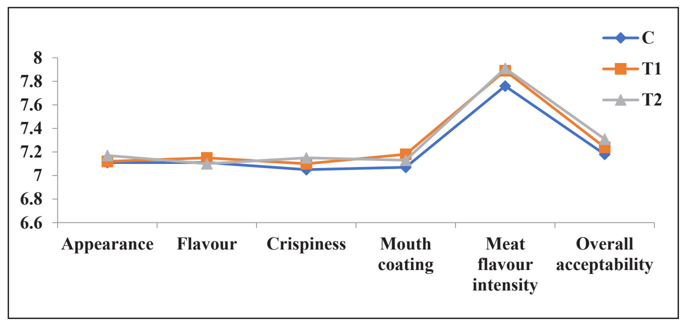

Fig. 9: Sensory analysis of chicken meat biscuits blended with oleogels

Physico-chemical characteristics

Both control (butter) and treatment (flaxseed oil oleogel) formulations experienced significantly decreased pH values (P<0.05) under both ambient (28±1°C) and refrigerated (4±1°C) storage temperatures (Table 4). Towards the end of the storage period, T_2 formulation exhibited notably lower pH values than the control, indicating elevated free fatty acid levels and chemical changes in the product. These findings align with Devalakshmi et al. (2010) in chicken meat chips, Mishra et al. (2015) in aerobically packed chicken meat rings, and Talukdar et al. (2015) in mutton snacks. However, they differ from the results reported by Shilpa et al. (2021) in chicken meat sausages with flaxseed oil oleogel.

Over the 45-day storage period, 2-TBARS values consistently increased significantly (P<0.05), regardless of storage temperature (Table 4). Chicken meat biscuits with flaxseed oil oleogel (T_2) consistently showed significantly lower (P<0.05) values compared to butter-incorporated biscuits (C) throughout storage. This can be attributed to antioxidants in flaxseed oil, such as phytosterols, vitamin E, and polyphenols, slowing down lipid peroxidation in the treat-

Table 4: Physico-chemical and microbiological quality of healthified chicken meat biscuits throughout ambient and refrigerated storage

Parameter	Treatments	Temperature of storage	Days of storage 0	8	16	24	32	40	44	Overall mean
pH	C	Ambient (28±1°C)	6.39±0.10	6.29±0.09	6.21±0.08	5.96±0.06	5.84±0.08	5.76±0.09	5.70±0.08	6.04±0.04^{x}
		Refrigerated (4±1°C)	6.39±0.10	6.36±0.12	6.31±0.08	6.17±0.08	6.13±0.15	5.99±0.20	5.90±0.12	6.21±0.04^{x}
	T_2	Ambient (28±1°C)	6.16±0.07	6.12±0.05	6.08±0.04	6.01±0.05	5.79±0.06	5.70±0.07	5.64±0.08	5.96±0.03^{y}
		Refrigerated (4±1°C)	6.16±0.07	6.11±0.05	6.06±0.05	6.00±0.05	5.95±0.17	5.90±0.18	5.81±0.14	6.01±0.03^{y}
2-TBARS	C	Ambient (28±1°C)	0.50±0.04	0.72±0.05	1.05±0.09	1.34±0.14	1.55±0.09	1.70±0.05	1.80±0.04	1.20±0.06^{x}
		Refrigerated (4±1°C)	0.50±0.04	0.85±0.03	1.34±0.17	1.59±0.16	1.79±0.05	1.87±0.02	1.90±0.02	1.39±0.06^{x}
	T_2	Ambient (28±1°C)	0.47±0.03	0.67±0.05	0.97±0.08	1.27±0.16	1.44±0.13	1.57±0.09	1.71±0.06	1.12±0.19^{y}
		Refrigerated (4±1°C)	0.47±0.03	0.79±0.07	1.17±0.19	1.42±0.17	1.61±0.06	1.72±0.04	1.77±0.05	1.26±0.06^{y}
TPC	C	Ambient (28±1°C)	0±0.0	0±0.0	0±0.0	0.42±0.11	0.85±0.04	1.35±0.25	1.51±0.24	0.51±0.0^{x}
		Refrigerated (4±1°C)	0±0.0	0±0.0	0±0.0	0.47±0.13	1.18±0.22	1.51±0.14	1.70±0.05	0.62±0.08^{x}
	T_2	Ambient (28±1°C)	0±0.0	0±0.0	0±0.0	0.14±0.04	0.74±0.07	1.11±0.25	1.13±0.16	0.37±0.06^{y}
		Refrigerated (4±1°C)	0±0.0	0±0.0	0±0.0	0.17±0.02	0.71±0.06	1.17±0.19	1.29±0.19	0.41±0.23^{y}
YMC	C	Ambient (28±1°C)	0±0.0	0±0.0	0±0.0	0±0.0	1.20±0.22	1.68±0.19	1.75±0.09	0.51±0.09^{x}
		Refrigerated (4±1°C)	0±0.0	0±0.0	0±0.0	0±0.0	1.39±0.19	1.71±0.09	1.78±0.06	0.64±0.10^{x}
	T_2	Ambient (28±1°C)	0±0.0	0±0.0	0±0.0	0±0.0	0±0.0	1.08±0.12	1.26±0.17	0.28±0.06^{y}
		Refrigerated (4±1°C)	0±0.0	0±0.0	0±0.0	0±0.0	1.01±0.15	1.03±0.14	1.18±0.13	1.34±0.12^{y}

• Note: Means holding common superscript in each row and column do not differ significantly.
• Significance: $P<0.05$

Table 5: Sensory quality of flaxseed oil oleogel incorporated chicken meat biscuits during storage

Parameter	Treatments	Temperature of storage	Days of storage							
			0	8	16	24	32	40	44	Overall mean
Appearance	C	Ambient (28±1°C)	7.06±0.02	6.80±0.08	6.46±0.05	6.31±0.07	6.18±0.03	6.11±0.05	6.05±0.02	6.44±0.04^{x}
		Refrigerated (4±1°C)	7.06±0.02	6.71±0.10	6.38±0.04	6.18±0.04	6.08±0.03	6.03±0.01	6.00±0.03	6.35±0.04^{x}
	T_2	Ambient (28±1°C)	7.16±0.02	7.06±0.04	6.88±0.07	6.61±0.07	6.45±0.07	6.27±0.12	6.17±0.08	6.69±0.04^{y}
		Refrigerated (4±1°C)	7.16±0.02	7.01±0.07	6.70±0.06	6.50±0.10	6.28±0.06	6.12±0.06	6.07±0.10	6.58±0.05^{y}
Flavour	C	Ambient (28±1°C)	7.04±0.02	6.76±0.06	6.43±0.03	6.26±0.06	6.15±0.04	5.99±0.04	5.95±0.05	6.39±0.04^{x}
		Refrigerated (4±1°C)	7.04±0.02	6.73±0.06	6.41±0.02	6.23±0.04	6.10±0.02	5.95±0.05	5.90±0.06	6.35±0.04^{x}
	T_2	Ambient (28±1°C)	7.10±0.05	6.95±0.06	6.80±0.03	6.56±0.05	6.38±0.08	6.14±0.04	6.02±0.03	6.61±0.04^{y}
		Refrigerated (4±1°C)	7.10±0.05	6.93±0.05	6.75±0.03	6.56±0.06	6.30±0.05	6.07±0.04	5.97±0.05	6.57±0.05^{y}
Crispiness	C	Ambient (28±1°C)	7.05±0.02	6.66±0.10	6.35±0.04	6.13±0.03	6.00±0.05	5.86±0.06	5.68±0.10	6.26±0.05^{x}
		Refrigerated (4±1°C)	7.06±0.02	6.63±0.07	6.36±0.03	6.15±0.04	6.00±0.06	5.79±0.06	5.65±0.08	6.26±0.05^{x}
	T_2	Ambient (28±1°C)	7.15±0.02	6.90±0.07	6.66±0.05	6.48±0.07	6.20±0.10	5.98±0.11	5.88±0.08	6.50±0.05^{y}
		Refrigerated (4±1°C)	7.16±0.02	6.95±0.08	6.63±0.05	6.43±0.13	6.18±0.10	5.99±0.08	5.87±0.06	6.49±0.05^{y}
Mouth coating	C	Ambient (28±1°C)	7.04±0.01	6.76±0.07	6.36±0.06	6.18±0.05	6.05±0.03	5.86±0.06	5.74±0.17	6.32±0.05^{x}
		Refrigerated (4±1°C)	7.04±0.01	6.70±0.04	6.35±0.03	6.16±0.04	6.05±0.02	5.90±0.06	5.78±0.05	6.31±0.05^{x}
	T_2	Ambient (28±1°C)	7.13±0.02	7.00±0.05	6.80±0.07	6.55±0.06	6.35±0.06	6.09±0.14	5.89±0.18	6.59±0.05^{y}
		Refrigerated (4±1°C)	7.13±0.02	6.91±0.04	6.66±0.03	6.48±0.06	6.18±0.06	6.01±0.08	5.87±0.05	6.50±0.05^{y}
Meat flavour intensity	C	Ambient (28±1°C)	7.73±0.22	7.26±0.18	6.96±0.20	6.65±0.09	6.40±0.05	6.13±0.04	6.05±0.02	6.78±0.07^{x}
		Refrigerated (4±1°C)	7.73±0.22	7.31±0.06	7.01±0.19	6.70±0.08	6.43±0.05	6.18±0.07	6.11±0.07	6.82±0.07^{x}
	T_2	Ambient (28±1°C)	7.90±0.16	7.45±0.10	7.21±0.17	6.81±0.05	6.53±0.05	6.32±0.06	6.17±0.08	6.96±0.07^{y}
		Refrigerated (4±1°C)	7.90±0.16	7.46±0.05	7.25±0.16	6.85±0.04	6.58±0.03	6.39±0.05	6.29±0.09	6.70±0.23^{y}
Overall acceptability	C	Ambient (28±1°C)	7.18±0.07	6.91±0.04	6.51±0.03	6.33±0.06	6.05±0.06	5.70±0.05	5.58±0.05	6.37±0.06^{x}
		Refrigerated (4±1°C)	7.18±0.07	6.95±0.04	6.56±0.05	6.35±0.03	6.10±0.03	5.73±0.04	5.58±0.06	6.41±0.06^{x}
	T_2	Ambient (28±1°C)	7.40±0.08	7.20±0.04	6.80±0.07	6.58±0.05	6.26±0.05	5.94±0.06	5.82±0.04	6.62±0.06^{y}
		Refrigerated (4±1°C)	7.40±0.08	7.23±0.04	6.86±0.05	6.61±0.05	6.31±0.04	6.00±0.04	5.85±0.04	6.67±0.06^{y}

• Note: Means holding common superscript in each row and column do not differ significantly.

• Significance: $P<0.05$

ment formulation. By the 45th day, all samples remained below the minimal malonaldehyde threshold, indicating acceptability throughout storage. Despite an increase in malonaldehyde content, the treatment formulation exhibited a slower rate of increase compared to the control formulation. The outcomes were consistent with those published by Kumar et al. (2016) in chicken meat biscuits, Kouzounis et al. (2017) in frankfurter sausages using sunflower oleogels, Zhu et al. (2020) in dry Harbin sausages by replacing animal fat with olive oil, and Shilpa et al. (2021) in chicken meat sausages with flaxseed oil oleogel.

Microbial quality

The total plate count and yeast and mold count of chicken meat biscuits significantly increased (P<0.05) during the 45-day storage period under both ambient (28±1°C) and refrigerated (4±1°C) conditions (Table 4). Higher total plate counts in refrigerated products may be due to moisture condensation. Chicken meat biscuits with flaxseed oil oleogel (T_2) consistently showed significantly lower counts (P<0.05) compared to the control for both total plate count and yeast and mold count, regardless of storage temperature. This can be attributed to the presence of phytosterols, polyphenolic compounds, and vitamin E in the flaxseed oil oleogel. Initially, both counts were undetected, possibly due to the low moisture content in the microwave oven-baked chicken meat biscuit. These findings were in well accordance with Devalakshmi et al., (2010) in chicken meat chips, Mishra et al., (2015) in aerobically packed dehydrated chicken meat rings and Sharmila et al., (2022) in chicken meat chips.

Sensory quality

Consumer preference for a product is greatly influenced by its initial appearance, reflecting freshness. Sensory scores in Table 5 revealed a notable decrease (P<0.05) in appearance scores for both control and treatment formulations during storage, regardless of temperature. The T_2 formulation consistently outperformed the control in appearance due to surface dehydration and myoglobin oxidation. Flavour exhibited a decreasing trend, possibly linked to lipid oxidation. The crispiness and intensity of meat flavor in both formulations were influenced by storage durations in both ambient and refrigerated settings. Nevertheless, the treatment formulation consistently received higher scores than the control, irrespective of the storage temperature. The overall acceptance of chicken meat biscuits was notably affected (P<0.05) by the formulation, storage temperature, and duration. Specifically, T_2 exhibited significantly higher acceptance scores under both storage conditions. The overall acceptability experienced a significant decline (P<0.05) with prolonged storage duration, which correlated with diminishing sensory scores and increased degradation of lipids, pigments, proteins, and fats. This trend aligned with findings in chicken meat chips by Sharmila et al. (2022), where a significant (P<0.05) decrease in sensory attributes occurred during storage.

CONCLUSION

Oleogels derived from plant-based oils rich in PUFA and MUFA offer a range of benefits when incorporated into chicken meat biscuits. Oleogels can effectively replace saturated fats in biscuits, contributing to a desirable texture that is both firm and moist. This structural modification can improve the overall palatability and appeal of the biscuits. Replacing saturated fats with PUFA and MUFA-rich oleogels significantly improves the nutritional value of the biscuits. These unsaturated fats are considered healthier for heart health and may reduce the risk of chronic diseases associated with excessive saturated fat intake. The positive findings from this research suggest that further optimization of the oleogel formulation can lead to even healthier and tastier products. By fine-tuning the oleogel composition and processing parameters, researchers can achieve a balanced flavour profile that appeals to consumers without compromising nutritional benefits. Overall, the introduction of oleogels derived from plant-based oils into chicken meat biscuits presents a promising strategy for developing healthier and more appealing products for consumers. By exploiting the unique properties of oleogels, food manufacturers can create products that are both nutritious and enjoyable to eat.

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