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UTILIZATION OF BIGEL STRUCTURES AS FAT REPLACERS IN TURKISH FERMENTED SAUSAGE: EFFECTS ON QUALITY AND PROCESSING

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I. INTRODUCTION

The detrimental health effects associated with the consumption of animal-derived fats have been extensively documented over recent decades (Hooper et al., 2020). In response to growing consumer awareness and the global shift toward healthier dietary habits, significant research efforts have been directed at developing innovative strategies to reduce saturated fat levels in meat products. One promising approach involves the use of bigels, or hybrid gels—semisolid, homogeneous systems comprising both an oleogel and a hydrogel phase. These systems offer considerable formulation versatility and have emerged as potential alternatives for animal fat replacement in processed meats (Kumari et al., 2022; Li et al., 2023). Bigels combine the functional advantages of both components, often allowing one phase to compensate for the limitations of the other (Singh et al., 2018). Turkish fermented sausage (*sucuk*), a traditional and widely consumed dry-fermented meat product, typically contains high levels of saturated fat. This characteristic has raised concerns among health-conscious consumers and contributed to decreased acceptance in recent years. Therefore, the present study aims to investigate the physicochemical and oxidative stability of *sucuk* formulations in which 50% of the total fat content is replaced with bigel structures containing oleogel:hydrogel at ratios of 50:50 and 60:40, respectively.

II. MATERIALS AND METHODS

Visible fat and connective tissue were removed from beef muscles prior to processing. The lean meat and beef fat were separately ground using a 3 mm plate. Subsequently, the minced meat and fat were transferred to a mixing machine (Mateka, Turkey), where curing agents, spices, and starter culture were added. The mixture was kneaded until homogeneous .Bigel formulations were prepared using oleogel structures composed of 90% rapeseed oil and different gelators: 10% carnauba wax (CW), 5% beeswax (BW), or 10% hydroxypropyl methylcellulose (HPMC). These were combined with a hydrogel phase consisting of 5% beef gelatin and 95% water. Oleogel and hydrogel phases were blended in two different ratios: 50:50 (coded as 50) and 60:40 (coded as 60), resulting in a total of six distinct bigel formulations. The inoculated meat mixtures were fermented at 20–25°C and 60% relative humidity for 4 hours, followed by further fermentation at 20–22°C and 80–85% relative humidity until the pH decreased to 5.4. Subsequently, the samples were ripened in a conditioning cabinet (DAIHAN, South Korea) at 18–20°C and 70–75% relative humidity until the moisture content dropped below 40%. Both pre-processed (dough) and post-processed (sucuk) samples were analyzed for fat content (Flynn and Bramblet, 1975), moisture content (AOAC, 2012), lipid oxidation (TBARS assay; Witte et al., 1970), color parameters (L*, a*, b*), pH, and water activity (aw).

III. RESULTS AND DISCUSSION

The results for total fat content, moisture content, pH, and color parameters for both the sucuk dough and final product, as well as the water activity of the final product, are presented in Table 1. As evident from the data, incorporating bigel structures as beef fat replacers significantly reduced the total fat content of the sucuk samples compared to the control. This reduction was influenced by the oleogel content within the bigel matrix; samples formulated with a 60:40 oleogel:hydrogel ratio exhibited higher fat content than those prepared with a 50:50 ratio. Moisture content was not significantly affected by fat replacement. Similarly, no statistically significant differences were observed in pH or water activity across treatments.Table 2 presents the TBARS and instrumental color analysis results. Contrary to previous findings reporting increased lipid oxidation in fat-reduced products (Zampouni et al., 2024; Siachou et al., 2023), the use of bigel structures did not significantly alter TBARS values either before or after processing. This outcome may be attributed to the intrinsic antioxidant properties of rapeseed oil used in the oleogel phase. In terms of color, fat-replaced dough samples appeared lighter than the control group. However, no consistent trend was observed between bigel composition and the a* (redness) and b* (yellowness) values following processing.

Table 1: Fat Content, Moisture Content, pH and a_w Values of Samples

Sample	Fat Content (%)		Moisture Content (%)		pH		a_w
	Dough	Sucuk	Dough	Sucuk	Dough	Sucuk	
Control	30.25±0.03^{a}	34.97±0.40^{a}	62.22±0.25	32.29±0.38	5.47±0.04^{ab}	5.29±0.02^{a}	0.921±0.001^{c}
CW50	19.73±0.48^{c}	23.73±0.76^{c}	62.35±0.48	31.64±0.43	5.51±0.02^{b}	5.44±0.03^{b}	0.923±0.001^{cb}
BW50	20.55±0.26^{c}	24.98±1.33^{c}	62.33±0.40	32.42±0.71	5.43±0.01^{a}	5.38±0.06^{b}	0.925±0.005^{cb}
HP50	20.07±0.20^{c}	25.18±2.80^{c}	62.37±0.90	32.11±0.26	5.45±0.02^{a}	5.42±0.05^{b}	0.926±0.002^{ab}
CW60	23.43±1.18^{b}	27.51±0.45^{b}	62.28±0.20	32.33±0.21	5.46±0.01^{a}	5.69±0.06^{b}	0.926±0.003^{ab}
BW60	23.30±0.52^{b}	27.87±0.47^{b}	62.68±0.51	31.94±0.41	5.42±0.03^{a}	5.82±0.03^{c}	0.928±0.002^{a}
HP60	23.25±0.43^{b}	27.77±0.30^{b}	62.58±0.40	31.75±0.63	5.46±0.05^{a}	5.73±0.01^{b}	0.925±0.001^{bc}

Different letters ($^{a–d}$) within the same column indicate significant differences between samples ($p < 0.05$).

Table 2: TBARS values and Color Parameters of Samples

Sample	TBARS (mg MA/kg Sample)		Color Parameters					
			Dough			Sucuk		
	Dough	Sucuk	L*	a*	b*	L*	a*	b*
Control	0.54±0.03	1.22±0.11	38.45 ±0.22^{a}	9.52 ±0.54^{a}	14.65 ±0.97^{a}	34.62 ±0.54	15.82 ±0.17^{a}	12.46 ±0.20^{a}
CW50	0.56±0.03	1.27±0.05	34.07 ±0.73^{b}	8.12 ±0.80^{b}	10.29 ±0.38^{b}	32.96 ±0.16	9.62 ±0.33^{b}	7.97 ±0.31^{bc}
BW50	0.56±0.03	1.24±0.11	34.20 ±1.34^{b}	7.58 ±0.62^{b}	10.24 ±0.75^{b}	32.74 ±3.55	8.79 ±0.35^{c}	7.44 ±0.99^{bc}
HP50	0.55±0.01	1.23±0.03	34.37 ±0.83^{b}	8.32 ±0.66^{b}	10.28 ±0.14^{b}	33.15 ±0.09	7.50 ±0.48^{d}	6.80 ±0.74^{c}
CW60	0.55±0.03	1.24±0.08	33.36 ±0.43^{b}	9.28 ±0.18^{a}	10.03 ±0.71^{b}	33.36 ±0.43	8.28 ±0.18^{c}	7.26 ±0.38^{bc}
BW60	0.56±0.02	1.27±0.01	33.73 ±0.43^{b}	9.41 ±0.36^{a}	10.04 ±0.25^{b}	33.39 ±0.18	7.41 ±0.36^{d}	7.52 ±0.32^{bc}
HP60	0.56±0.01	1.29±0.01	33.12 ±0.21^{b}	10.00 ±0.32^{a}	10.35 ±0.53^{b}	31.99 ±0.44	7.23 ±0.26^{d}	7.35 ±0.54^{bc}

Different letters ($^{a–d}$) within the same column indicate significant differences between samples ($p < 0.05$).

IV. CONCLUSION

In this study, the utilization of six different bigel structures as 50% beef fat replacement was assessed in terms of physicochemical attributes and oxidative stability during processing. Fat-replaced samples were found to contain lower levels of total fat when compared to the control group, with the oleogel ratio being a factor between replaced groups, as 60:40 ratio bigels displayed higher fat content results than their 50:50 counterpart. Additionally, no statistical significance was found between the fat-replaced and control groups in terms of oxidative stability during processing. As a result, bigel structures are found to be a viable option for decreasing the total fat content of meat products in terms of short-term oxidative stability.

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