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INNOVATIVE APPLICATION OF CHITOSAN-BASED GELLED EMULSION ENRICHED WITH POMEGRANATE SEED OIL AS A BEEF FAT REPLACER IN MODEL MEAT SYSTEM

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I. INTRODUCTION

Meat is valued for its essential nutrients such as amino acids, vitamins, and minerals; however, concerns about its high fat and cholesterol content have led to a growing demand for healthier alternatives. To overcome the negative effects of fat reduction on sensory and technological qualities, recent research focus on solutions like gelled emulsions, hydrogels, and organogels [1]. Gelled emulsions (GEs) have a semi-solid structure formed by proteins and/or polysaccharides that can replicate the texture of saturated fats by dispersing oil droplets. They offer a healthier alternative by enabling the use of polyunsaturated fatty acid-rich oils to improve the lipid profile of food products [2]. Chitosan, a versatile and biocompatible polymer derived from shellfish, is widely used due to its biodegradability, antimicrobial properties, and functional roles in various applications such as stabilization, gelling, and drug delivery [3]. Pomegranate seed oil, rich in punicic acid and other bioactives, is known for its health-promoting properties and has been used in various fields including animal nutrition, food packaging, and as a functional and antimicrobial ingredient in food formulations [4]. Although the positive effects of chitosan and pomegranate seed oil are well-documented, there is no study that utilizes them together in a GE formulation or in meat products as a fat replacer. Therefore, this study aims to investigate the effects of using a GE formulated with chitosan and pomegranate seed oil as a beef fat replacer in model meat systems, focusing on chemical composition and technological properties.

II. MATERIALS AND METHODS

Beef and beef fat were purchased locally in Izmir for model meat emulsions (MEs). The meat was processed within 48 h postmortem. Chitosan (80% deacetylation) and pomegranate seed oil were supplied by Nurbal Şifa Aktar and Smart Kimya, respectively, while curing agents were from Fansada Aroma. Analytical-grade chemicals were sourced from Sigma-Aldrich. An O/W GE was prepared with 10% chitosan in the water phase, which was heated to 65°C. The oil phase, consisting of pomegranate seed oil, was heated to 55°C. The water and oil phases were emulsified in a Thermomix at 5800 rpm for 3 min. The prepared gel emulsions were left to structure at 4°C for 24 h. MEs were produced according to Çalişkan et al. [1]. The control group (C) was formulated with 20% beef fat, while in the other groups, beef fat was replaced by GE at ratios of 50% (GE50), 75% (GE75), and 100% (GE100), respectively. Moisture and ash content were specified following the AOAC [5], fat content was assessed using the method outlined by Flynn and Bramblet [6], and protein content was analyzed through the Dumas burning method utilizing the LECO Protein/Nitrogen Analyzer (model FP-528, Leco, St. Joseph, MI, USA). The pH value of the MEs was measured by immersing the pH meter (WTW pH 330i/SET) at four different points with the immersion tip. Emulsion stability was determined following the protocol outlined by Hughes et al. [7]. The processing yield, moisture retention [8], and fat retention [9] were calculated by weight differences for MEs before and after cooking. The production in this study was carried out in two independent batches, and samples from each batch were analyzed in triplicate. Data were analyzed using ANOVA and Duncan's test (SPSS 23).

III. RESULTS AND DISCUSSION

The addition of GE had a significant impact on the chemical composition of model meat emulsions (Table 1). As the ratio of GE increased, a notable increase in fat content was observed in GE75 and GE100, while moisture and ash content decreased ($P < 0.05$). On the other hand, the protein content of treatments showed variability independent of the GE ratio, with the highest value observed in the group containing 50% GE, whereas GE100 had the lowest value with the control group ($P < 0.05$). The ash content of the samples decreased regardless of the amount of gelled emulsion added, with the highest value observed in the control group ($P < 0.05$).

Table 1. Chemical composition of model meat emulsions

Chemical Composition	Treatments*			
	C	GE50	GE75	GE100
Moisture (%)	64.45±0.30^{a}	64.57±0.37^{a}	62.48±0.32^{b}	63.05±0.86^{b}
Fat (%)	12.77±0.53^{b}	10.52±1.21^{c}	14.33±0.48^{a}	15.03±0.71^{a}
Protein (%)	20.09±0.56^{b}	22.47±1.06^{a}	20.71±0.58^{ab}	19.43±1.40^{b}
Ash (%)	2.71±0.01^{a}	2.46±0.09^{b}	2.50±0.14^{b}	2.47±0.01^{b}

*C: meat emulsions prepared with 100% beef fat; GE50: meat emulsions prepared with 50% GE; GE75: meat emulsions prepared with 75% GE; GE100: meat emulsions prepared with 100% GE. [a-c]:Different letters in the same row indicate a statistically significant difference ($P < 0.05$).

Techno-functional properties of model meat emulsions were presented in Table 2. The pH values of the samples increased regardless of the amount of GE added, with the highest values observed in the GE75 and GE100 ($P < 0.05$). This can be explained by the alkaline pH (~6.50) of chitosan used in the GE formulation. Emulsion stability is an indicator of the amount of fat and water retained in the matrix by meat proteins. Regardless of the utilization ratio, the addition of GE resulted in a significant increase in the total amount of expressible fluid, with the highest value observed in the GE75 ($P < 0.05$). In parallel with the TEF values, the groups containing 50% and 75% GE showed an increase in total expressible fat, while the GE100 exhibited the lowest value ($P < 0.05$). This finding can be attributed to the ability of the GE to enhance fat retention within the matrix. In contrast, the highest EFAT value was observed in the GE50 (23.19%) ($P < 0.05$). The amount of separated gel and fat increased regardless of the added GE level, with the lowest value observed in the control group ($P < 0.05$). This result is consistent with the emulsion stability results. The processing yield values ranged from 63.05% to 89.71%. The highest value was found in the control group, while a decrease was seen in the reformulated groups, regardless of the GE usage level ($P < 0.05$). The GE75, with the highest TEF value, exhibited the lowest moisture retention ($P < 0.05$). When examining fat retention, a decrement was observed as the GE ratio in the formulation increased ($P < 0.05$).

Table 2. Techno-functional properties of model meat emulsions

Parameter	Treatments*			
	C	GE50	GE75	GE100
pH	6.18±0.00^{c}	6.36±0.01^{a}	6.31±0.00^{b}	6.32±0.01^{b}
Total Expressible Fluid (TEF) (%)	8.10±0.68^{c}	28.91±1.14^{b}	34.46±0.58^{a}	27.47±1.24^{b}
Total Expressible Fat (EFAT) (%)	14.24±1.07^{c}	23.19±0.91^{a}	21.33±0.58^{b}	10.95±0.20^{d}
Gel and Oil Separation (%)	13.87±0.87^{b}	28.14±1.69^{a}	29.85±0.09^{a}	28.30±1.45^{a}
Processing Yield (%)	89.71±0.04^{a}	66.53±1.03^{c}	63.05±0.60^{d}	70.18±0.21^{b}
Moisture Retention (%)	55.55±0.02^{a}	43.21±0.67^{b}	37.51±0.36^{c}	43.88±0.13^{b}
Fat Retention (%)	87.56±0.04^{a}	74.97±1.16^{b}	71.70±0.68^{c}	58.41±0.89^{d}

*C: meat emulsions prepared with 100% beef fat; GE50: meat emulsions prepared with 50% GE; GE75: meat emulsions prepared with 75% GE; GE100: meat emulsions prepared with 100% GE. [a-d]:Different letters in the same row indicate a statistically significant difference ($P < 0.05$).

IV. CONCLUSION

The addition of gelled emulsion significantly affected the chemical composition, with increased fat content and decreased moisture and ash as GE ratio increased. The highest protein content was observed in the 50% GE, while pH values increased due to the alkaline nature of chitosan. Emulsion stability improved with GE, however fat retention decreased as the GE ratio increased, suggesting moderate GE levels (50% and 75%) offer the best balance for fat replacement. Overall, GE shows promise as an effective beef fat replacer in meat products, offering potential for further development in reduced-fat meat formulations.

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