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Improvement of Erişte (Homemade Pasta) with Grasshopper Powder: Effects on Nutritional, Physicochemical and Sensory Properties

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ABSTRACT

The high nutritional value of edible insects, particularly their richness in protein and micronutrients, presents a sustainable solution to meet the growing global demand for food. This study investigated the enrichment of erişte (traditional Turkish homemade pasta) formulations with grasshopper powder (GP) at a wheat flour substitution level of 0-15% to assess its effect on the nutritional values, textural and sensory properties of erişte samples. As the level of GP substitution increased, the nutritional values (protein, ash and total phenolic content) of the samples improved significantly ($p<0.05$). Adding 15% GP to the erişte recipe increased the protein content by up to 60%. Concerning textural parameters; erişte enriched with GP showed a significantly ($p<0.05$) softer structure with lower adhesiveness, cohesiveness, chewiness and resilience whereas no significant differences ($p>0.05$) were observed in all textural properties except chewiness and resilience between samples with GP. The sensory panel rated the erişte fortified with 5% GP similar to the control sample, whereas erişte with more than 5% fortification received lower scores, primarily due to its darker color and distinct odor. Consequently, these results suggest that GP has the potential as an ingredient to improve the nutritional value of pasta products such as erişte.

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Introduction

The anticipated diminishment of food resources attributable to population growth is poised to precipitate disruptions within the food supply chain in subsequent years (Amiri et al., 2023). Hence, the development of novel food sources emerges as a critical determinant for ensuring food sustainability in forthcoming times. Presently, one of the foremost challenges stemming from population expansion lies in the dwindling availability of protein sources. In this vein, the burgeoning demand for alternative food sources is escalating progressively. The notion of addressing the protein deficit amid food crises by substituting traditional sources such as cattle and sheep with edible insect species is gaining increasing traction (van Huis et al., 2013).

Of the 1.4 million animal species identified in the world, 1 million are insects (Karaman, 2024). Edible insects are emerging as a promising source of high-quality protein, gaining attention as an alternative to conventional animal-based foods. In 2013, the Food and Agriculture Organisation (FAO) published a report entitled "Edible Insects: Future Prospects for Food and Feed Security," which provides a comprehensive analysis of insect consumption and argues that edible insects will be a sustainable food source in the future. Insects represent one of the most promising alternative solutions for addressing the challenge of meeting global protein demands. Their high protein content, favourable amino acid composition, and relatively low environmental production costs render them particularly advantageous compared to traditional protein sources (Jantzen da Silva Lucas et al., 2020). Therefore, there has been increased interest in research on using edible insects as alternative protein sources. In addition, edible insects exhibit various biological activities, including antioxidant and antimicrobial effects (del Hierro et al., 2020; Rahnamaeian et al., 2015).

Among the roster of edible insects, grasshoppers stand out as one of the most widely consumed species globally. Grasshoppers are ubiquitously consumed across the globe, comprising approximately 13% of all edible insect species. They contain a substantial amount of highly digestible

protein, at almost 800 g/kg (dry basis). Furthermore, they are a good source of key essential amino acids, including lysine and leucine (Rumpold & Schlüter, 2013; Karaman & Girgin, 2020). In addition, from the point of view of human consumption, health and hygiene, the grasshopper is almost one of the cleanest feeding insects in the world (Premalatha et al., 2011). Despite grasshoppers typically reproducing only once per year, they contribute significantly to global biomass. Numerous grasshopper species worldwide are edible, and their consumption has been a longstanding practice across various cultures throughout history. In terms of nutrient content, grasshoppers are leaner and richer in protein than beef, lamb, chicken and fish (Durst et al. 2010). In addition to these, grasshoppers also contain potassium and phosphorus minerals (Ssepuuya et al., 2017). Traditionally consumed in countries such as South America and China, grasshoppers are not accepted in Western societies due to neophobia and disgust (Verbeke, 2015). According to the results of the study conducted in Turkey, only 20% of participants expressed positive thoughts and behaviours regarding locust consumption (Karaman & Bozok, 2023). To integrate insects into the Western diet, overcoming the initial resistance to their consumption is crucial. As one of the most promising alternative sources to solve the problem of meeting the global protein requirement, the use of grasshopper in food formulations in the form of flour rather than as a whole seems to be a solution that will eliminate this obstacle. (Tan et al., 2015).

Traditional Turkish homemade pasta, commonly known as erişte, is a staple food that is widely consumed in Turkey. This pasta-like product is made by kneading and shaping wheat flour with water, salt, eggs and sometimes additional optional ingredients (Demir et al., 2010). Although primarily a Turkish dish, erişte is referred to by different names across various countries, and shares similarities with pasta in terms of both production methods and raw materials (Koca et al., 2018). They are known for their ease of production and widespread consumption, and offer the potential to be enriched with numerous functional and nutritional components. Due to its properties, erişte is an excellent basis for new food product development and fortification. Numerous studies have explored enhancing the nutritional value of pasta by incorporating different protein sources, including legume flours, cheese, soy protein, mustard protein isolate, and gluten flour (Sadehi & Bhagya, 2008; Petiot et al., 2010). The most important issue in pasta fortification is to find a substitute product that offers improved nutritional and/or technological advantages over durum wheat. No research has been conducted on enhancing erişte with grasshoppers, prompting the design of this study to examine the utilization of grasshopper powder.

This study aimed to produce an enriched and functional product by adding GP at certain ratios (5%, 10% and 15%) instead of wheat flour in the composition of erişte. The effects of enrichment with GP on some quality parameters such as nutritional value, cooking quality, functional, textural, colour (*L*, *a*, *b*) and sensory properties of erişte were evaluated and compared with erişte produced only from wheat flour.

Materials and Methods

Materials

Migratory grasshopper, *Locusta migratoria* (Orthoptera: Acrididae) was obtained from Mira Ltd. Şti. (Antalya, Turkey). Wheat flour, eggs and milk were purchased at the local market.

Grasshopper Powder

The harvest of live grasshoppers obtained from the company was carried out after freezing at -20 °C, following ethical rules to minimise oxidation stress reactions and to kill the insects without suffering. Frozen grasshoppers were soaked in 80% alcohol solution, placed on grids and dried in a ventilated oven at 50 °C for 40 h. The dried grasshoppers were first ground into powder with a mortar and pestle after the wings and legs were separated, then powdered into a fine powder with a grinder (Arzum AR1060 Multivit, Türkiye) and sieved through a 150 µm sieve and sealed in vacuum bags. GP was stored at -18 °C for analysis.

Erişte Making Procedure

Erişte dough was prepared by mixing wheat flour, GP, milk, egg and water in certain ratios. The dough containing GP was formulated by replacing wheat flour with 5, 10 and 15% GP. The sample without GP was used as a control. The ingredients were thoroughly mixed and kneaded with tap water (pH 6.8) for 10 minutes. A laboratory pasta-making machine was used to make 50 mm long and 1 mm thick erişte samples. The samples were dried at 60 °C until they reached a final moisture content of 11%. Each group of samples was then placed on foam trays (approximately 500 g per tray), wrapped with cling film, and stored at room temperature (23 °C) in the dark until analysis. The formulations of the samples are given in Table 1.

Nutritional Values

The nutritional content of both the erişte samples and grasshopper flour was analyzed. The ash, moisture, fat, and protein content of the samples were determined following AACC methods (AACC, 1990). The total amount of carbohydrates was obtained by calculating the difference between 100% of the dry matter and the sum of ash, fat, and protein percentages.

Table 1. Formulation of erişte samples (120 g sample) (g)

Ingredients (g)	Control	GP5	GP10	GP15
Wheat flour	80	76	72	68
Grasshopper powder	-	4	8	12
Egg	10	10	10	10
Milk	10	10	10	10
Water	20	20	20	20

Control, GP5, GP10, and GP15 denote erişte with GP at 0, 5, 10, and 15 % (*w*/*w*), respectively.

Texture Profile

Texture analysis of the samples was performed using a texture analyser (TA HD Plus Texture Analyzer Surrey, UK) equipped with a 10 kg load cell and a 36 mm diameter cylindrical probe. The test speed was measured as 2 mm/s. Hardness, adhesiveness, springiness, cohesiveness, chewiness, and resilience were assessed during the test (AACC, 1990).

Color Characteristics

A colorimeter (Chroma Meter CR-400, Konica Minolta, Japan) was employed to evaluate the color parameters (L^*, a^*, b^*) of the raw erişte samples, where L^* indicates lightness, a^* denotes redness/greenness, and b^* represents yellowness/blueness. Prior to measurements, the device was calibrated six times using a standard white calibration plate. The total color difference (ΔE*) between the control and the treated samples was calculated using the following equation: (Goswami et al., 2015):

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (1)$$

Total Phenolic Content (TPC)

The TPC in the samples was determined using a spectrophotometric technique involving Folin-Ciocalteu reagent, based on a modified procedure from Wolfe et al. (2003). The sample (0.5 mL) was reacted with 2.5 mL of 10% Folin–Ciocalteu reagent and 2 mL of 75% (w/v) Na_2CO_3. The sample mixture was vortexed briefly (15 seconds) and subsequently incubated for 90 minutes at room temperature to facilitate color development. The absorbance of the samples was recorded at 720 nm using a UV/visible spectrophotometer. The TPC was quantified as mg/100 g gallic acid equivalents (GAE) of sample, calculated from a calibration curve.

Sensory Evaluation

To prepare the samples, 500 mL of unsalted water was boiled with 200 g of erişte for 20 min, and the mixture was then drained. The twenty panelists evaluated the taste, odour, colour, texture and overall acceptability of the cooked erişte samples. A seven-point hedonic scale, with 1 as 'extremely disliked' and 7 as 'extremely liked,' was used to assess each parameter.

Data Analysis

Statistical data analysis was conducted using the JMP© 7.0 software (SAS Institute, Inc.). To assess the significance of differences between samples over the storage period, a two-way analysis of variance (ANOVA) was performed. Significant differences were further analyzed and grouped using the Tukey test at a 5% significance level.

Results and Discussion

Composition And Function Properties of GP And Erişte Samples

Table 2 presents the chemical composition (moisture, fat, protein carbohydrate, ash) and functional properties of GP and samples that have been supplemented with 0–15% grasshopper powders. GP primarily consisted of protein and fat, with carbohydrates and ash present in smaller amounts. GP presented protein and ash values similar to those previously reported by Çabuk & Yılmaz (2020). However, the fat value reported in this paper are higher than those reported by Çabuk & Yılmaz (2020).

The moisture content plays a crucial role in influencing both the shelf life and microbiological quality of pasta-like products. The results indicated that the moisture content of erişte samples fortified with GP ranged from 8.20 ± 0.18% to 12.80 ± 0.41%, with samples containing 10% and 15% GP retaining less moisture compared to both the control and those fortified with 5% GP. This outcome may be attributed to the high fat content, which likely inhibited water evaporation during the baking process (González et al., 2019). Consistent with the findings of our study, previous reports have shown that the use of insect powders in cookies (Sriprablom et al., 2022), as well as various insect flours like grasshopper flour in egg pasta (Çabuk & Yılmaz, 2020), increased the moisture content compared to control samples.

The incorporation of GP into the erişte led to an increase in protein, fat, ash, and total phenolic content. Erişte enriched with 150 g/kg GP exhibited significantly higher nutritional values, with protein content increasing by more than 50% compared to the control sample. Concerning the substitution ratio, the crude protein content of the erişte samples increased with an increase in the substitution ratio. Similar to the protein content, the elevated ash content in erişte samples with higher substitution ratios could be linked to the high ash content of the GP. Replacing wheat flour with 15% GP increased the fat content from 2.02 ± 0.12% to 8.52 ± 0.29% with a corresponding decrease in carbohydrate content from 73.73 ± 0.29% to 60.99 ± 0.41%.

Table 2. Nutritional composition (%) of grasshopper powder and erişte samples enriched with 0–15% grasshopper powders

Parameters	Erişte samples				Grasshopper powder
	Control	GP5	GP10	GP15	
Moisture (%)	11.20±0.25^a	12.80±0.41^a	8.20±0.18^b	9.20±0.27^b	4.2
Protein (%)	12.83±0.16^d	16.10±0.12^c	17.17±0.08^b	20.17±0.17^a	53.38
Fat (%)	2.02±0.12^d	6.19±0.52^b	4.33±0.34^c	8.52±0.29^a	17.04
Carbohydrate (%)	73.73±0.29^a	64.23±0.38^c	69.42±0.23^b	60.99±0.41^d	2.73
Ash (%)	0,22±0.02^d	0.68±0.04^c	0.88±0.04^b	1.12±0.03^a	5.9
TPC (mg GAE·kg^{-1})	27.67±7.42^d	52.58±5.21^c	86.71±9.13^b	129.15±12.34^a	348.54

Control, GP5, GP10, and GP15 denote erişte with GP at 0, 5, 10, and 15 % (*w*/*w*), respectively. Mean values marked with different letters (a–d) are significantly different at $p < 0.05$.

The fact that GP contain more protein and fat than wheat flour explains the higher protein, fat and ash content. A similar pattern was reported in studies by Çabuk (2021) and Haber et al. (2019), where an increase in the level of GP resulted in higher protein and fat content in the muffin and bread samples.

The TPC of the erişte samples was found to range between 27.67 (control) and 129.15 mg GAE/100 g (15% GP). The increase in GP substitution rate led to a superior increase in total phenolic content. This result confirmed that GP is rich in phenolic compounds.

Color Characteristics of Erişte Samples

Color is a key quality factor influencing food acceptability because it is closely tied to perceptions of freshness and flavor, directly impacting how consumers view the product. The visual appearance of erişte samples enriched with 0–15% GP is presented in Table 3. GP5, GP10 and GP15 received ΔE values higher than 2.3 (3.52, 2.92 and 3.29, respectively), that corresponds to a noticeable difference between the samples and control. This result confirms that the changes in erişte color were significant enough to be easily seen by consumers. Previous research has indicated that color differences become visually noticeable when ΔE exceeds 3.0 (Çabuk, 2021; Bellary et al., 2016). This suggests that the color change caused by the use of the additive is quite noticeable, which can significantly reduce its appeal to consumers.

Incorporation of GP significantly ($p<0.05$) affected the *L**, *a** and *b** values of erişte samples (Table 2). As GP replaced flour, the erişte color gradually darkened. However, this effect was not dependent on the concentration of GP for *L** value. The darker color formation in insect powder-fortified erişte samples might be attributed to their higher protein content and the inherent color of the insect powders themselves, compared to the control sample. The results of the color analysis showed that all formulations with GP led erişte samples with increased redness (*a**) compared to control sample. Moreover, replacing wheat flour with GP decreased the yellowness (*b**) in samples. The yellow color of the erişte reduced with increasing substitution level of GP ($p<0.05$).

In general, these results indicated that the erişte samples became darker and redder and bluer when the GP was incorporated, which is in good agreement with previous edible insect-based studies (Çabuk & Yılmaz, 2020; Çabuk, 2021; Sriprablom et al., 2022).

Textural Properties of Erişte Samples

Erişte texture is the most crucial quality indicator affecting consumer acceptance. Hardness values of erişte samples varied between 15024 g and 22527 g (Table 4). The hardness and adhesiveness of erişte samples fortified with GP were higher than those of the control sample, as indicated by texture analysis ($p<0.05$). However, no significant effect ($p>0.05$) of the rate of GP incorporation was found for these textural parameters. The harder texture in the fortified samples compared to the control can be attributed to the weaker and denser gluten network formed by the addition of GP (Haber et al., 2019). In addition, literature data suggests that high protein ingredients (insect powder, egg, broad bean) used in the production of pasta and cookies (Laleg et al., 2016; Sriprablom et al., 2022) may have contributed to a harder texture, consistent with the results of this study, due to the strong hydrogen bonding between protein and starch that occurs during dough development and baking (Inglett et al., 2015). High-quality pasta is often characterized by both considerable hardness and minimal loss during cooking, according to previous reports (Bruneel et al., 2010).

In this study it was found that the cohesiveness, chewiness and resilience of the erişte samples also increased significantly ($p<0.05$) with the addition of GP, and this increase became more pronounced when the substitution ratio was increased from 5 to 10%.

Similar observations were reported by Çabuk (2021), who noted a decrease in the adhesiveness, cohesiveness, chewiness and resilience of muffins enriched with grasshopper and mealworm powders. The springiness value refers to the ability of the samples to return to their original, undeformed state after the applied deformation is removed. The springiness values of samples were in the range of 0.80–0.83 and no significant differences ($p > 0.05$) were found among the samples.

Table 3. Color characteristics of control and enriched erişte samples

Sample	Color parameters			
	*L**	*a**	*b**	ΔE
Control	88.90±0.01^{a}	-0.01±0.01^{d}	2.87±0.01^{a}	-
GP5	86.87±0.01^{b}	0.20±0.01^{a}	1.43±0.03^{b}	3.52
GP10	86.52±0.02^{b}	0.13±0.02^{b}	1.19±0.02^{c}	2.92
GP15	86.21±0.01^{b}	0.06±0.01^{c}	0.97±0.01^{d}	3.29

Control, GP5, GP10, and GP15 denote erişte with GP at 0, 5, 10, and 15 % (*w*/*w*), respectively. Mean values marked with different letters (a–d) are significantly different at $p < 0.05$.; *L**: lightness; *a**: redness; *b**: yellowness; ΔE: total color difference.

Table 4. Textural properties of control and enriched erişte samples

Parameters	Erişte samples			
	Control	GP5	GP10	GP15
Hardness (g)	22527±358^{a}	15736±175^{b}	16099±443^{b}	15024±644^{b}
Adhesiveness (g.sn)	-177.45±19^{a}	-257.52±21^{b}	-250.46±46^{b}	-239.49±28^{b}
Springiness	0.80±0.01^{a}	0.81±0.06^{a}	0.82±0.02^{a}	0.83±0.05^{a}
Cohesiveness	0.47±0.02^{a}	0.41±0.01^{ab}	0.33±0.01^{b}	0.35±0.01^{b}
Chewiness	8379±268^{a}	5188±196^{b}	4400±180^{c}	4381±200^{c}
Resilience	0.16±0.01^{a}	0.14±0.01^{b}	0.10±0.01^{c}	0.11±0.01^{c}

Control, GP5, GP10, and GP15 denote erişte with GP at 0, 5, 10, and 15 % (*w*/*w*), respectively. Mean values marked with different letters (a–c) are significantly different at $p < 0.05$.

Sensory Properties of Erişte Samples

Figure 1 presents the sensory evaluation results of the erişte samples fortified with GP in comparison to the control. In the sensory evaluation of the erişte samples, panelists rated their preferences for taste, odor, texture, color, and overall acceptability using a 7-point hedonic scale.The control sample, made without GP, received the highest ratings across all sensory attributes and overall acceptability. It was shown that consumer evaluations in terms of taste and color did not change significantly ($p>0.05$) with the addition of 5% GP, but the acceptability of the samples in terms of these parameters decreased with further increase in the substitution ratio ($p<0.05$). The dark brown colour of GP may have a negative impact on panellists' colour scores. In terms of odor, sample GP15 had the lowest sensory score, followed by samples GP5 and GP 10 with similar scores. For texture, no significant difference was received between the samples. The overall acceptability results indicate that the addition of GP affects the overall approval of the erişte samples. The control sample had the highest score (5.0), while the most acceptable erişte sample closely resembling the control was GP5 (4.6). A similar effect of grasshopper on odour and general liking was also observed by Haber et al. (2019), who observed a decreasing trend in general preference with increasing GP in bread samples.

In general, the results showed that the enrichment of GP, especially at 10% and above, had negative effects on the sensory qualities. The lower acceptability ratings could be linked to the erişte's darker color, unique smell, and denser texture due to the addition of GP. However, erişte enriched with 5% GP was moderately appreciated with an average score of 5.2, close to the control sample. A low proportion of additives can result in erişte with high consumer acceptance.

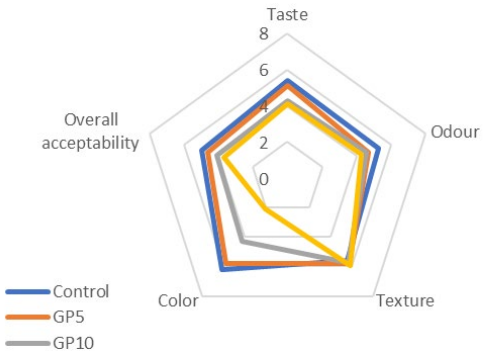

Figure 1. Sensory evaluation of control and enriched erişte samples (Control, GP5, GP10, and GP15 denote erişte with GP at 0, 5, 10, and 15 % (w/w), respectively)

Conclusion

In this study, erişte (Turkish homemade pasta), a traditional product known by various names in the Middle East region, was enriched with GP and the effect of using GP at different ratios instead of wheat flour on nutritional values, textural and sensory properties of erişte samples was investigated. The results clearly demonstrated that fortification of the erişte samples with GP significantly improved their nutritional profile, with emphasis on protein content. As the substitution ratio increased from 0% to 15%, the crude protein content of erişte samples increased from 12.83% to 20.17%, the ash content increased from 0.22% to 1.12%, and total phenolic content increased from 27.67 mg GAE/100 g to 129.15 mg GAE/100 g. The addition of GP to the formulations led to the erişte being softer and less sticky than the control sample. In addition, the high (10 and 15%) concentrations of GP significantly reduced the sensory ratings of the erişte samples for all sensory attributes except texture due to its unpleasant odour and dark colour, while the erişte with 5% GP received similar ratings to the control sample in the sensory tests.

This study demonstrated that GP can be effectively added to erişte to increase its nutritional value, particularly its protein and bioactive content. However, the sensory analysis results indicated that the concentration of GP should be carefully considered.

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