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Formulation and Nutritional Evaluation of Fenugreek and Date Enriched Ragi Bars for Polycystic Ovary Syndrome Management

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A B S T R A C T

Polycystic Ovary Syndrome (PCOS) is a prevalent endocrine disorder in women of reproductive age often associated with insulin resistance, oxidative stress and obesity. The present study aimed to formulate and evaluate fenugreek and date-enriched ragi bars for their potential therapeutic benefits in PCOS management. Four treatments were developed using varying levels of fenugreek powder T0 (control), T1 (5%), T2 (10%) and T3 (15%). Nutritional assessment included proximate analysis, antioxidant profiling, caloric value estimation and sensory evaluation over a 30-day storage period. Among all treatments T1 (5% fenugreek powder) showed the most balanced nutritional profile and highest sensory acceptability. The mean values (±SD) for key parameters in T1 at 0 days were moisture content 10.46 ± 0.01%, ash 2.07 ± 0.02%, protein 7.72 ± 0.01%, fat7.04 ± 0.01%, fiber 5.07 ± 0.01% and caloric value 390.55 ± 0.01 kcal/100g. Antioxidant activity assessed by DPPH radical scavenging showed the highest value in T2 (10% fenugreek) with 66.66 ± 0.01%, while the total phenolic content peaked in T3 (15% fenugreek) with 5.36 ± 0.01% GAE. Sensory evaluation indicated that T1 was most preferred by the panel with a taste score of 7.73 ± 0.02, and maintained acceptable quality over 30 days. Statistical analysis revealed that treatment type and storage duration significantly affected most parameters ($p < 0.05$), whereas their interaction was generally non-significant.In conclusion, fenugreek and date- enriched ragi bars particularly at 5% fenugreek inclusion exhibited optimal nutritional, functional and sensory qualities supporting their use as functional dietary interventions in managing PCOS.

Keywords: Antioxidants, Fenugreek powder, Functional food, Pcos, Ragi bars, Sensory evaluation.

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INTRODUCTION

Polycystic Ovary Syndrome (PCOS) is among the most common endocrine disorders affecting women of reproductive age. It is associated with various symptoms, including polycystic ovaries, hyperandrogenism (elevated male hormones), and irregular menstrual cycles however, the specific presentation can differ from one individual to another (Teede et al., 2010). PCOS is associated with metabolic disorders such obesity, insulin resistance, heart disease and type 2 diabetes and also fertility. Relying on the diagnostic criteria used estimates of the prevalence of PCOS range globally starting from 6% to 20% (Barthelmess & Naz, 2014). PCOS is more frequently observed in South Asia, where both genetic predisposition and lifestyle factors play a significant role. In certain urban populations, it can affect as many as 26% of women. This high rate underscores the need for increased awareness and targeted management strategies for women in these areas (Keya, 2017).

The prevalence of PCOS is quite higher in Pakistani women, 52 % as compared to western Caucasian women (Sidra et al., 2019). PCOS symptoms include acne, hirsutism (extra body hair), thinning scalp hair, weight gain, and mood swings (Dewailly et al., 2010). Functional

foods help to manipulate continual illnesses inclusive of PCOS especially those that are enhanced with bioactive (Mollazadeh et al., 2019). Inside this framework the formulation of Ragi (*Eleusine coracana*) bars enhanced with fenugreek (*Trigonella foenum-graecum*) and dates (*Phoenix dactylifera*) is a unique approach for providing PCOS sufferers a nutrient-dense finger food with health benefits. Ragi rich in nutritional fiber, calcium, and amino acids (Shobana et al., 2013). Because of its hypoglycemic and insulin-resistence properties fenugreek has been utilized for centuries for its potential to help regulate blood sugar levels. Recent studies are investigating its effectiveness in treating polycystic ovary syndrome (PCOS) (Neelakantan et al., 2014).

Additionally, dates are not only a rich source of natural sugars but also packed with various minerals and nutrients. They may boost energy levels and possess antioxidant properties (Baliga et al., 2011).Honey has traditionally been utilized in traditional medication. It is possible that this is probably useful for women who suffer from polycystic ovary syndrome (PCOS), who are often at a higher risk of cardiovascular issues. It is viable that people with polycystic ovary syndrome (PCOS) would possibly gain from using it as a greater nutritious alternative to processed candies for the cause of controlling their blood sugar level because it has a low glycemic index (Erejuwa et al., 2012).Almonds are an essential factor for women who effect by polycystic ovarian syndrome (PCOS) that is a condition that impacts menstrual cycles. The oxidative stress that is often related to polycystic ovarian syndrome (PCOS) can be reduced by using almonds which can also be an outstanding supply of antioxidants (Eslampour et al., 2021). According to Bozdag et al. (2016) there are signs associated with reproduction, metabolism, and intellectual nation which are related to PCOS.

METHODOLOGY

The study was carried out at Riphah International University, Faisalabad. Selected ingredients were analyzed for their nutritional properties and ragi bars were prepared using different proportions of fenugreek, ragi, dates, almonds and honey. The formulated bars were then evaluated for their proximate composition and antioxidant activity.

Sample	Ragi	Honey	Almond	Date	Fenugreek seed powder
T0	35	35	10	20	----
T1	35	20	25	15	5
T2	25	20	20	25	10
T3	25	25	15	20	15

Ragi bars were developed according to the respective protocol mentioned by (Paresh & Lal, 2020). Recipe of the bars is selection of raw material; cleaning of raw material; removing seeds from dates; grinding fenugreek seeds and ragi; roasting almonds and ragi; mixing and grinding all ingredients; adding honey; preparation of bars and packaging and storage.

The Ragi bars enriched with fenugreek and dates were analyzed for moisture, ash, crude protein, crude fat, crude fiber and NFE by following protocols of (AACC, 2023).

The Ragi bars enriched with fenugreek and dates were analyzed for moisture, ash, crude protein, crude fat, crude fiber and NFE by following protocols of (AACC, 2023). The energy content of bars will be measured by bomb calorimeter (Sharma et al., 2014). The calorific value was calculated using the equation:

Energy value(Kcal100 g)=(4×% CHO)+ (9×% fat)+ (4×% protein) Carbohydrate content was determined by the difference method;

$$\text{Carbohydrate (\%)} = 100 - (\%\ \text{moisture} + \%\ \text{fat} + \%\ \text{protein} + \%\ \text{ash} + \%\ \text{fiber})$$

The TPC in bar samples was find out by following the method described by Allai et al., 2022. The extraction procedure was carried out using methanol as the solvent. Twenty milliliters of methanol were used to homogenize two grams of samples. After that, the homogenate was left alone for 12 hours. For fifteen minutes the resulting mixture was centrifuged at 10,000 × g. Following centrifugation, 1.2 ml of 7.5% Na2CO3 and 1.5 ml of Folin-Ciocalteu reagent are combined with 0.2 ml of the aliquot. After that, the mixture was left at 25°C for two hours. Lastly, a spectrophotometer set at 765 nm was used to measure the absorbance. The TPC was showed as mg gallic acid equivalents (GAE)/g of dry material after gallic acid was used to create a calibration curve.

The antioxidant activity of the samples was assessed using the DPPH radical scavenging method, following the procedure outlined by Kowalska et al. (2021). Sample extraction was carried out using 80% methanol at 25°C for a duration of 120 minutes. The resulting extracts were then filtered through Whatman No. 1 filter paper. A 100 µL aliquot of each extract was mixed with 3.9 mL of DPPH solution. After a 30-minute incubation period at room temperature, the absorbance was recorded at 517 nm to evaluate the radical scavenging activity.

Sensory evaluation of Fenugreek and Date Enriched Ragi Bars was performed by (Aramouni & Abu-Ghoush, 2011). The sensory evaluation was conducted in individual booths at the Department of Human Nutrition and Dietetics, Riphah International University, Faisalabad, Pakistan. After the completion of the study obtained data was statistically analyzed by applying complete randomized design (CRD) according to the protocol defined by (Montgomery, 2017). Bars were stored for 30 days at room temperature. The prepared bars were stored in air tight boxes.

RESULTS AND DISCUSSION

Ovary Syndrome (PCOS)

The study involved several key stages including the preparation of fenugreek seed powder formulation of bars using ragi flour, fenugreek seed powder, dates, honey and almonds and development of product variations based on different ingredient concentrations. The developed bars underwent a thorough proximate study to evaluate their nutritional composition, which included moisture, protein, fat, fiber and ash content. Furthermore, the calorific value was determined to estimate energy contribution, and the total phenolic content and antioxidant properties were examined using the DPPH radical scavenging method to investigate potential functional advantages. Lastly, sensory evaluation was conducted to evaluate customer acceptability based on taste, texture, aroma, appearance and overall preference.

Ananthan et al. (2021) the development of nutrient-rich energy bars using ingredients like cereals, pulses and dried fruits the initial moisture content ranged from 10.2% to 11.4%, with a gradual increase observed during 30 days of ambient storage. The authors attributed the moisture increase to environmental humidity and the hygroscopic nature of ingredients like dates and oats. Kumar et al. (2024) millet-based health bars enriched with flaxseed and jaggery, reporting moisture values between 10.5% and 11.3%, with a statistically significant increase ($p < 0.05$) over 30 days of storage. Like fenugreek, flaxseed also exhibited hygroscopic behavior, increasing water retention. This trend matches the pattern in present study where higher fenugreek levels (T2 and T3) retained more moisture over time.

Singh et al. (2015) tthe development of high-fiber biscuits enriched with fenugreek and defatted soy flour. The ash content of the biscuits ranged from 2.08% to 2.35%, depending on the level of fenugreek powder incorporation. A significant increase in ash content was observed with the rising levels of fenugreek similar to current study where T2 (10% fenugreek) consistently had the highest ash content (2.27%–2.32%). The results also showed slight fluctuations over storage, which aligns with the statistically significant treatment*day interaction in present findings.

Yadav and colleagues (2017) protein contents ranging from 7.1% to 7.8%, depending on the concentration of added fenugreek and legumes. A significant improvement in protein content was observed with the addition of 5% fenugreek, closely matching the T1 group in your study (7.72% at day 0, decreasing to 7.58% by day 30). The study also noted a slight but consistent decline in protein during storage similar. Ahmad et al. (2022) fat content ranged from 6.3% to 8.5%, depending on formulation and storage. Products with lower fenugreek concentrations (5–10%) showed significantly lower fat content consistent with your T1 and T2 values. Ranasinghe et al. (2022) high-fiber functional bars developed using plant-based ingredients including fenugreek, it was found that fiber levels remained stable during storage up to 30 days under ambient conditions. The minor decline in fiber content was attributed to moisture absorption and minimal enzymatic activity which did not significantly affect the functional value of the product.

T3 (15% fenugreek powder) exhibited the highest total phenolic content (5.36%), followed by T1 (4.72%), T2 (4.63%), and the control group T0 (4.63%). This suggests that a higher level of fenugreek powder (15%) substantially enhanced the antioxidant capacity of the ragi bars. Fenugreek seeds are naturally rich in phenolic compounds, and their increased addition played a direct role in boosting the bars functional properties against oxidative stress a crucial aspect in PCOS management.

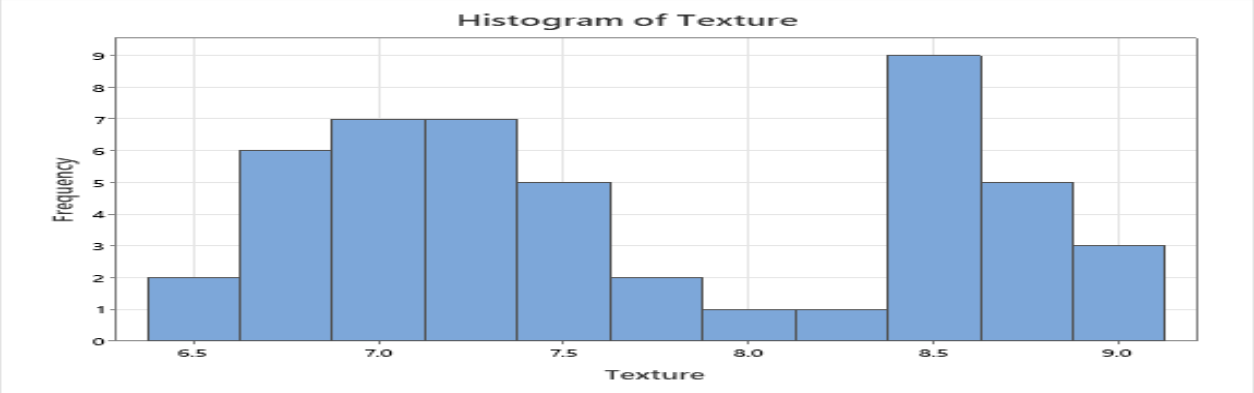
At the start (0 day), T2 (10% fenugreek powder) showed the highest DPPH value (66.66%), T3 (15% fenugreek, 62.57%) (Table 4.8) Interestingly, the 10% fenugreek treatment (T2) displayed better antioxidant activity than even the control, suggesting that moderate levels of

fenugreek powder enhanced the free radical scavenging potential of the bars.

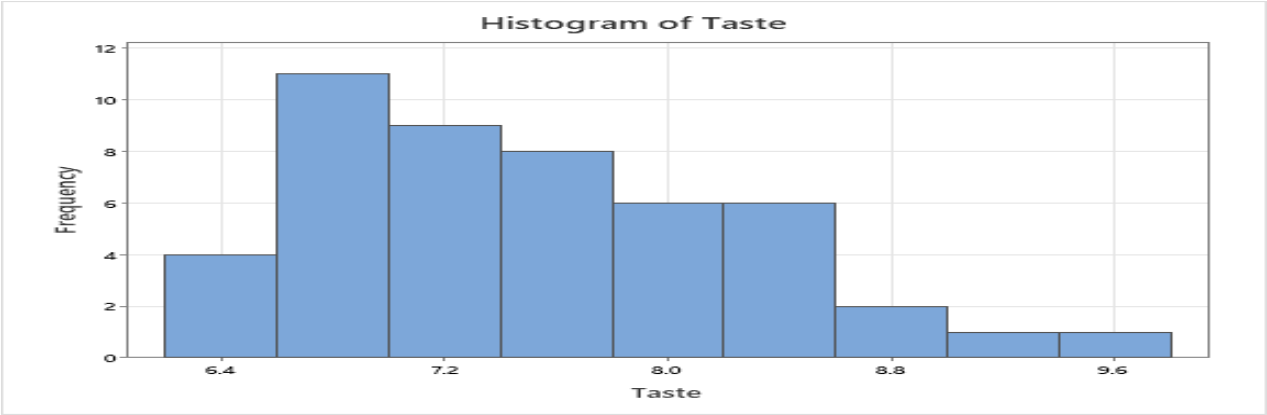
Treatment	0 day	10 day	20 day	30 day
T0	4.63±0.01[a]	4.55±0.01[a]	4.46±0.01[a]	4.37±0.01[a]
T1	4.72±0.01[a]	4.63±0.01[a]	4.56±0.01[a]	4.47±0.01[a]
T2	4.62±0.01[a]	4.54±0.01[a]	4.45±0.01[a]	4.37±0.01[a]
T3	5.36±0.01[a]	5.27±0.01[a]	5.33±0.01[a]	5.13±0.01[a]

At the 10-day mark. T1 (5% fenugreek powder) consistently showed the highest texture scores (8.9 on day 10, 8.8 on day 20, and 8.5 on day 30), indicating that the texture of this treatment improved over time. This suggested a beneficial impact of fenugreek powder on maintaining or enhancing texture during storage, which could be attributed to changes in the moisture content and the gel-like properties of the bars.

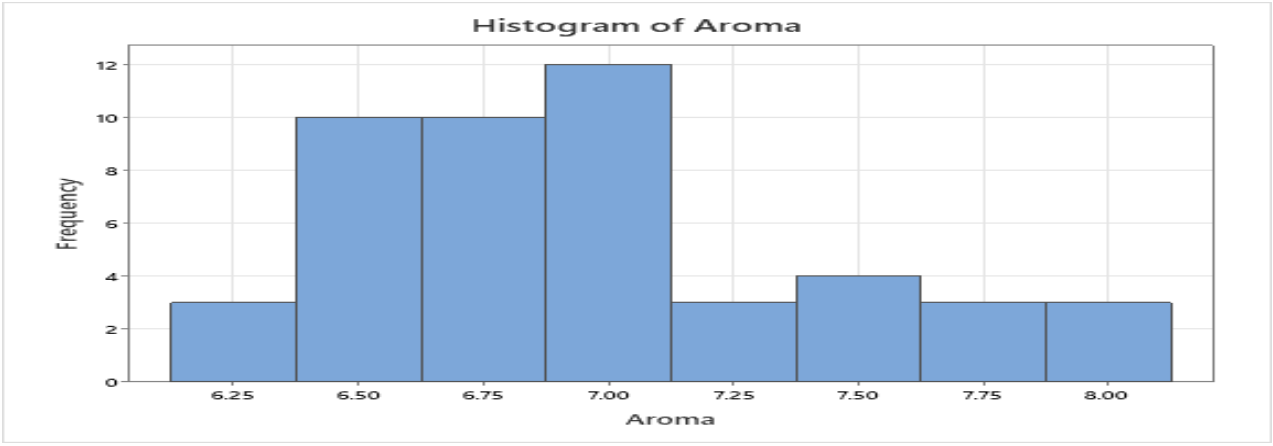
Treatment	0 day	10 day	20 day	30 day
T0	64.98±0.01[a]	64.48±0.02[b]	63.98±0.01[a]	63.47±0.01[a]
T1	62.88±0.01[a]	62.38±0.01[a]	61.88±0.1[c]	61.38±0.01[a]
T2	66.66±0.01[a]	66.16±0.02[b]	65.67±0.02[b]	65.16±0.02[b]
T3	62.57±0.01[a]	62.07±0.02[b]	61.56±0.02[b]	61.06±0.02[b]



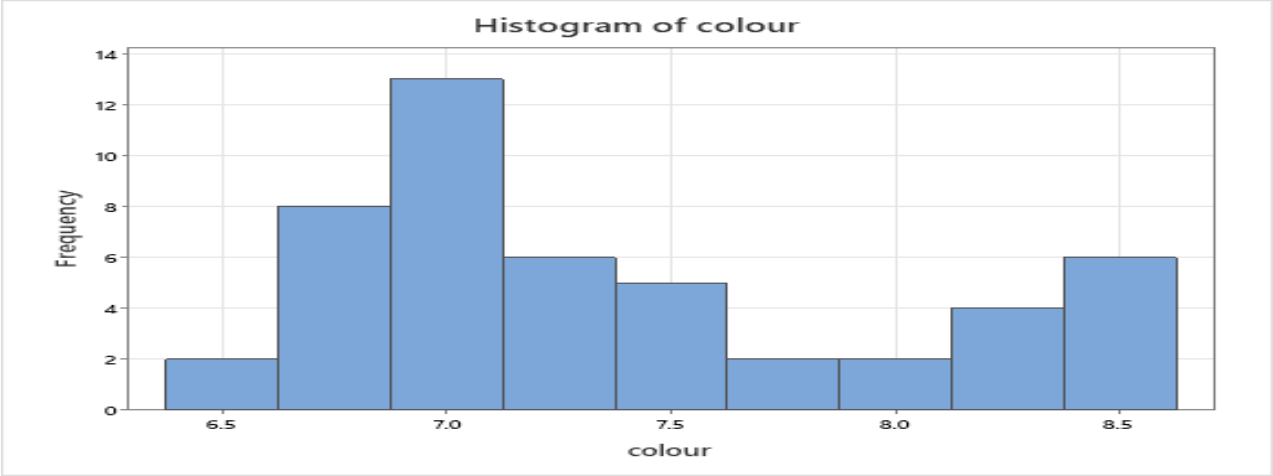
Taste scores improved notably by the 10th day across all treatments, peaking at that point: T1 (9.1), T0 (8.47), T2(8.3), and T3 (8.1). This increase could be due to flavor maturation over time. However, a gradual decline in taste scores was observed by the 20th and 30th days, indicating that prolonged storage slightly deteriorated sensory quality, possibly due to flavor degradation or changes in the product matrix over time.



Aroma scores fluctuated for different treatments. The 5% fenugreek powder group (T1) maintained the highest aroma score throughout the storage period, with a peak of 7.83 on day 10, followed by a slight decrease to 7.17 by day 20 and 7.03 by day 30. This suggests that the 5% fenugreek powder treatment not only provided an enhanced aroma initially but also retained its pleasant scent throughout the storage period. For the other treatments, particularly T2 (10% fenugreek powder) and T3 (15% fenugreek powder), aroma scores fluctuated but showed a decline over time. T2 showed scores of 6.67 on day 10, 7.00 on day 20, and 6.80 on day 30. Similarly, T3 started at 6.6 on day 10, peaked at 7.2 on day 20 and decreased again to 6.6 by day 30. These results indicate that while the aroma of higher fenugreek concentrations improved slightly at day 20, it did not maintain consistency over time and decreased by day 30.



The color of the ragi bars changed across treatments. The control group (T0) resulted a decline in color over the 30-day storage period with scores decreasing from 8.5 on day 10 to 7.3 by day 30. This reflects a slight fading of color as the bars aged. Similarly, T1 (5% fenugreek powder) experienced a gradual decline from 8.43 on day 10 to 7.1 on day 30, but it remained relatively consistent compared to the control. For T2 (10% fenugreek powder) and T3 (15% fenugreek powder), the color initially dropped slightly from day 0 to day 10, with T2 scoring 8.3 and T3 scoring 8.1. However, by day 30, the color of these treatments showed a noticeable decline, reaching 6.8 for both T2 and T3. This suggests that higher concentrations of fenugreek powder resulted in a less stable cooler over time, possibly due to the influence of fenugreek's natural characteristics on the overall appearance of the bars. Overall acceptability is a crucial factor for consumer preference, encompassing a combination of taste, texture, aroma, color, and other sensory attributes. The ANOVA analysis.



Treatment	0 day	10 day	20 day	30 day
T_0	7.16±0.02[b]	7±0.01[a]	6.8±0.01[a]	6.7±0.01[a]
T_1	8.05±0.01[a]	7.96±0.01[a]	7.84±0.01[a]	7.75±0.01[a]
T_2	7.3±0.02[b]	7.1±0.02[b]	6.8±0.01[a]	6.8±0.01[a]
T_3	7.6±0.01[a]	7.4±0.01[a]	7.33±0.01[a]	7±0.01[a]

The formulation, nutritional assessment, and functional characteristics of fenugreek and date-enriched ragi bars created for the dietary control of polycystic ovarian syndrome (PCOS) are thoroughly examined in this chapter. A 30-day storage period was used to evaluate the bars, which were made with different amounts of fenugreek seed powder (5%, 10%, and 15%). A thorough proximate analysis showed that the addition of fenugreek affected important nutritional parameters: its hygroscopic nature caused the moisture content to rise with increasing fenugreek levels; its ash content, which indicates mineral richness, peaked at 10% inclusion; and its protein and fiber contents significantly improved at 5% concentration, indicating optimal nutritional enhancement without sacrificing stability. The formulation, nutritional assessment, and functional characteristics of fenugreek and date-enriched ragi bars created for the dietary control of polycystic ovarian syndrome (PCOS) are thoroughly examined in this chapter. A 30-day storage period was used to evaluate the bars, which were made with different amounts of fenugreek seed powder (5%, 10%, and 15%). A thorough proximate analysis showed that the addition of fenugreek affected important nutritional parameters: its hygroscopic nature caused the moisture content to rise with increasing fenugreek levels and its ash content which indicates mineral richness peaked at 10% inclusion and its protein and fiber contents significantly improved at 5% concentration indicating optimal nutritional enhancement without sacrificing stability.

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