

## Original Research

Received 01 June 2026

Revised 17 July 2026

Accepted 29 July 2026

Natural Resources for Human Health 2026, Vol. 6 (13s): 991–1005

### KEYWORDS:

PCOS, PCOD, Nutrition, Granola

## Development and Nutritional Profiling of Cinnamon-Based Polyherbal Granola for Management of Polycystic Ovarian Disorder

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**ABSTRACT:** Polycystic ovarian disorder (PCOS) is a predominant endocrine-metabolic disorder categorized as insulin resistance, hormonal imbalance, and chronic inflammation, requiring directed dietary interventions. The current research has developed and nutritionally profiled a cinnamon-based polyherbal granola formulation appropriate for the management of PCOS. Fifteen formulations were created and assessed based on macronutrient and micronutrient configuration. A multi-criteria decision-making (MCDM) approach using the Analytic Hierarchy Process (AHP) was functional to allocate methodically resulting weights to acute nutritional constraints, containing protein, sugar, magnesium, zinc, lipid profile, sodium, and energy content. Combined nutritional scores were calculated to classify the most appropriate formulation.

Amongst all samples, Formulation 11 established higher nutritional features, comprising the lowest sugar content (10.4 g/100 g), highest protein (18 g/100 g), prominent magnesium (188 mg/100 g) and zinc (3 mg/100 g), and a promising unsaturated fat profile. The reliability ratio (CR = 0.026) established the reliability of the AHP model. Sensory assessment by means of a 9-point hedonic scale with seven trained panelists specified high suitability across taste, texture, aroma, color, and overall acceptability, with mean scores above 7.5.

The outcomes specify that Formulation 11 effectively assimilates metabolic functionality with sensory appeal, representing possible functional cereal-based dietary involvement for PCOS management. In terms of methodological limitations, glycemic index was not measured experimentally. Also, metabolic functionality is inferred rather than directly tested. This study proposes a nutritionally balanced composition with potential dietary significance in PCOD control, although it makes no claims regarding therapeutic efficacy. Additional clinical validation is suggested to measure long-term therapeutic effectiveness.

## INTRODUCTION

Polycystic Ovarian Disorder (PCOD) or Polycystic Ovarian Syndrome (PCOS) is a hormonal and metabolic disorder that usually affects women of reproductive age. This problem usually occurs when women's hormones are out of balance. This has become a more prominent issue these days in India due to lack of awareness in young age women. PCOS, if not treated, can lead to severe health problems such as diabetes and heart diseases. If left undiagnosed, it can also cause infertility in women.

Studies have shown that approximately 5% to 10% young women of childbearing age between 15 and 44 have PCOS. Most of these women find out about their PCOS in the 2<sup>nd</sup> and 3<sup>rd</sup> decade of their lives. This is usually diagnosed when women have irregular menstrual cycle, face difficulty in getting pregnant or presence of tiny ovarian cysts has been detected. Studies have also shown that in India, one in five women have PCOS while in East India, the number is one in four. 18% of Indian population, mostly from the East suffer from PCOS (Anjali et al., 2019).

Nutrient intake in all forms is very important for an effective management of PCOS. Other than this, following regular exercise routine and consuming healthy diet is optimal to cure PCOS at the earliest before it causes any further harm to the women's body. There is no optimum amount of carbohydrate intake for women suffering with PCOS. Any range between 40% and 55% can be adopted which is mainly dependent on individual's dietary assessment, habits, preferences, and metabolic goals. However, higher amount of protein intake is necessary and can yield positive health outcomes which includes increased weight loss, improved glycaemic control, preservation of lean mass during weight loss and maintenance, and mitigation of other CVD risk factors such as blood pressure. Thus, adding 7gm to 15gm of protein into the daily diet of PCOS women can prove beneficial. In terms of fat, it is observed that low-fat hypocaloric diet can help in reducing body weight and composition as compared to high-fat hypocaloric diet. Low carbohydrate and high fat diets decrease fasting insulin, improve metabolic parameters, and increase insulin sensitivity in women with PCOS. Women with PCOS often consume unhealthy diets that are deficient in essential nutrients such as calcium, zinc, vitamins, omega-3 fatty acids, fibre, and magnesium. Several micronutrients like chromium, selenium, carotenoids, zinc, and vitamin E have potential benefits in improving the metabolic condition of women with PCOS. Thus, such essential nutrients should be added in the diet of PCOS women (Pandey & Niroula, 2024). All these nutrients need to be consumed by PCOS women to maintain their health and meet their metabolic goals. Therefore, nutrient-rich granola is being produced that are good in taste, easy to consume, and fulfil the energy requirements of a PCOS women's body. The research conducted by (Karnavat & Chaudhari, 2023) formulated a millet-based protein-mineral enriched granola that was composed of pearl millet, ragi crispy, sorghum, jiggery, amaranth puff, and moong dal. This composition in a granola is found to be very effective in tackling malnutrition. The addition of amaranth puff in this composition is merely for providing a crispy texture to lure women into regular consumption of the granola. This millet-based granola is a nutridense snack that is easy to prepare, affordable, and is more cost-effective than the normal commercial granola. With the addition of protein and mineral products, this granola provides the necessary nutrients and minerals to women's body to tackle PCOD. More such compositions of granola can also be effective in managing PCOD in women. Thus, the present study aims to produce a cinnamon-based polyherbal granola with a different composition to analyze its management and effectiveness in women's body with PCOS.

Based on the above discussion it was observed that the available literature on granola formulations majorly focus on macronutrient enhancement (protein, fibre, minerals). These do not sufficiently include therapeutically relevant herbs such as cinnamon which is specifically known for its potential role in glycaemic regulation and metabolic improvement in PCOS. Also, the available literature has dietary guidelines properly stated for PCOS but there is absence of appropriate, nutritionally profiled, sensory-acceptable, and condition-specific ready-to-eat products custom-made for PCOS condition in women. Therefore, the current research has coped up with these gaps by developing and nutritionally profiling a cinnamon-based polyherbal granola precisely boosted for PCOS controlling using a organized multi-criteria assessment method.

## MATERIAL AND METHODS

### Materials

A blend of several ingredients has been used to compose cinnamon-based polyherbal granola. Among the dry ingredients, rolled oats, chopped almonds, chopped cashews, flax seeds, chia seeds, fenugreek seeds, and cinnamon have been used.

Among the wet ingredients, honey or maple syrup, melted coconut oil, and vanilla extract as an optional ingredient has been used. Herbal additions of ashwagandha powder and shatavari powder have also been made into the composition. Some researches have tested the feasibility of ashwagandha powder and shatavari for PCOS (Ande et al., 2022; Dhankani et al., 2023; Wani et al., 2025).

## Preparation of Granola

To prepare the granola, firstly the oven has been preheated. Thus, oven has to be set to 160 degree Celsius/320 degree Fahrenheit. Then, baking sheet needs to be lined with parchment paper. All the dry ingredients (rolled oats, chopped almonds and cashews, flax seeds, chia seeds, fenugreek seeds, and cinnamon) are to be mixed in a large bowl and all the wet ingredients (honey or maple syrup, melted coconut oil, and vanilla extract) are to be mixed in a separate small bowl until they are well-combined. Then, the wet mixture can be poured onto the dry ingredients and have to be stirred until the entire mixture is evenly coated. Then, stir the herbal powders namely ashwagandha powder and shatavari powder over the mixture and stir to incorporate the herbal texture in the entire mixture. Now the mixture is ready to spread evenly onto the prepared baking sheet. The mixture was baked for 20 to 25 minutes at 160 degree Celsius, stirring halfway through, until the granola is golden brown and fragrant. Now, the granola is ready and can be removed from oven. Once the granola is completely cooled on the baking sheet, they can be broken into clusters and stored in an airtight container at room temperature for up to two weeks.

## Nutritional Analysis Methodology Clarification

All nutritional parameters were analyzed by a NABL-accredited laboratory using validated standard protocols (FSSAI manual and AOAC methods). The following methodological details have now been specified in the revised manuscript:

1. Zinc & Magnesium: SOP-CHM-27-01 (Part A)
2. Energy: SOP-CHM-29-00
3. Carbohydrate: SOP-CHM-28-00
4. Total Fat: SOP-CHM-100-01
5. Added Sugar: SOP-CHM-139-00
6. Protein: SOP-CHM-137-00
7. Cholesterol & Fatty Acid Profile (SFA, MUFA, PUFA, Trans fat): AOAC 994.10 & AOAC 996.06
8. Sodium: SOP-CHM-27-01 (Part A)

All analyses were conducted using calibrated instruments under standard laboratory quality control procedures. Samples were tested in accordance with FSSAI guidelines, and results were reported per 100 g of product.

A total of 15 formulations of the granula have been created. The details of the formulations have been presented below (Table 1)-

**Table 1.** Different formulations of Granola Considered in the Research.

| Formulations | Almond (%) | Cashew (%) | Flax (%) | Chia (%) | Oats (%) | Added Sugar (g/100g) |
|--------------|------------|------------|----------|----------|----------|----------------------|
| F1           | 25         | 25         | 5        | 5        | 40       | 10.5                 |
| F2           | 17.27      | 22.73      | 15       | 5        | 40       | 9.8                  |
| F3           | 15.35      | 10         | 9.65     | 5        | 60       | 12                   |
| F4           | 21.25      | 15.99      | 5        | 5        | 52.76    | 11.2                 |
| F5           | 13.51      | 20         | 15       | 10       | 41.49    | 9.3                  |
| F6           | 25         | 25         | 15       | 5        | 30       | 10                   |

|     |       |      |       |      |       |      |
|-----|-------|------|-------|------|-------|------|
| F7  | 10    | 25   | 15    | 5    | 45    | 11.6 |
| F8  | 25    | 10   | 15    | 5    | 45    | 10.8 |
| F9  | 15    | 25   | 10    | 15   | 35    | 9.1  |
| F10 | 17.54 | 20   | 10    | 7.46 | 45    | 10.7 |
| F11 | 25    | 25   | 15    | 5    | 30    | 9.8  |
| F12 | 25    | 10   | 15    | 5    | 45    | 10.9 |
| F13 | 19.25 | 19.6 | 10.94 | 7.73 | 51.73 | 11.4 |
| F14 | 19.25 | 25   | 5     | 10   | 40.75 | 10.2 |
| F15 | 10    | 15   | 5     | 10   | 60    | 12.3 |

These formulations were tested in lab for nutritional analysis. Once the results were obtained, there optimization was conducted to identify the best composition.

## Optimization

For optimization, Multi-Criteria Decision Making (MCDM) method has been used. Herein, MCDM using the Weighted Sum Model was applied to rank the formulations based on multiple nutritional parameters relevant to PCOS management. The formulation with the highest composite score was considered most suitable.

For Weighted Sum Model, weights were assigned based on clinical and nutritional relevance to PCOS management. For this, the research considered insulin regulation (sugar and protein), metabolic micronutrients (magnesium and zinc), and lipid quality (unsaturated and saturated fat), as supported by current nutritional guidelines for PCOS. The weight intensity and reason behind opting for specific intensity are as below-

**Table 2.** Parameter wise weight intensity and reason behind opting for specific intensity.

| Parameter       | Weight Intensity | Reason                                                                                                                                                                                                                         | Reference                  |
|-----------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Protein         | Very High        | Improves satiety, reduces cravings, and reduces insulin spikes. Since weight and insulin regulation play a key role in PCOS, protein was provided very high weight.                                                            | (Stefanaki et al., 2024)   |
| Sugar           | Very High        | Directly linked to insulin resistance. Since, sugar control is a major nutritional goal, thus it was provided very high weight.                                                                                                | (Li et al., 2022)          |
| Magnesium       | High             | Improves metabolic profile and insulin sensitivity while reducing inflammation. Thus, it plays an important role in management of PCOS but slightly less when compared to sugar and protein. Thus it was provided high weight. | (Shahmoradi et al., 2024a) |
| Unsaturated fat | High             | Anti-inflammatory and support hormonal balance which is important in PCOS management but not as critical as insulin control. Thus it was provided high weight.                                                                 | (Armanini et al., 2022)    |

|               |        |                                                                                                                                                  |                        |
|---------------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| Zinc          | Medium | Facilitates in hormonal regulation and ovulatory function. Thus, it is important but indirect compared proceeding parameters                     | (Kapper et al., 2024)  |
| Saturated fat | Medium | Should be limited as these increases insulin resistance and promote inflammation. Thus it was provided medium weight.                            | (Thomas et al., 2023)  |
| Sodium        | Low    | Indirect metabolic role hence has a low priority in PCOS. Thus it was provided low weight.                                                       | (Lorenzo et al., 2023) |
| Energy        | Low    | As granola is consumed in portion sizes, the energy density matters but can be controlled through serving size. Thus it was provided low weight. | (Chu et al., 2024)     |

The exact quantitative weights were decided based on Analytic Hierarchy Process (AHP). For this, firstly Pairwise Comparison Matrix was constructed based on method suggested by Saaty, (1977). The used Saaty's 1–9 scale is as below-

- 1 = Equal importance
- 3 = Moderate importance
- 5 = Strong importance
- 7 = Very strong
- 9 = Extreme

Thus, the constructed Pairwise Comparison Matrix is as below (Table 3)-

**Table 3.** Pairwise Comparison Matrix.

|             | Prot | Sug  | Mg   | Zn    | Unsat | Sat   | Sod   | Ene   |
|-------------|------|------|------|-------|-------|-------|-------|-------|
| Protein     | 1    | 1    | 3    | 3     | 3     | 5     | 7     | 7     |
| Sugar       | 1    | 1    | 3    | 3     | 3     | 5     | 7     | 7     |
| Magnesium   | 1/3  | 1/3  | 1    | 2     | 2     | 3     | 5     | 5     |
| Zinc        | 1/3  | 1/3  | 1/2  | 1     | 2     | 3     | 5     | 5     |
| Unsat Fat   | 1/3  | 1/3  | 1/2  | 1/2   | 1     | 3     | 5     | 5     |
| Sat Fat     | 1/5  | 1/5  | 1/3  | 1/3   | 1/3   | 1     | 3     | 3     |
| Sodium      | 1/7  | 1/7  | 1/5  | 1/5   | 1/5   | 1/3   | 1     | 2     |
| Energy      | 1/7  | 1/7  | 1/5  | 1/5   | 1/5   | 1/3   | 1/2   | 1     |
| Column Sums | 3.49 | 3.49 | 8.73 | 10.23 | 11.73 | 20.67 | 33.50 | 35.00 |

Pairwise comparisons for nutritional criteria were conducted using Saaty's 1–9 fundamental scale. The comparisons were based on clinical evidence related to PCOS prioritizing insulin regulation (protein and sugar), metabolic micronutrients (magnesium and zinc), and lipid quality (unsaturated and saturated fat). Reciprocal values were allocated to maintain matrix uniformity.

Normalizing the Pairwise Comparison Matrix, the resultant matrix is as below (Table 4)-

**Table 4.** Normalized Pairwise Comparison Matrix.

|           | Prot | Sug  | Mg   | Zn   | Unsat | Sat  | Sod  | Ene  |
|-----------|------|------|------|------|-------|------|------|------|
| Protein   | 0.29 | 0.29 | 0.34 | 0.29 | 0.26  | 0.24 | 0.21 | 0.20 |
| Sugar     | 0.29 | 0.29 | 0.34 | 0.29 | 0.24  | 0.24 | 0.21 | 0.20 |
| Magnesium | 0.10 | 0.10 | 0.11 | 0.20 | 0.17  | 0.16 | 0.15 | 0.14 |
| Zinc      | 0.10 | 0.10 | 0.06 | 0.10 | 0.17  | 0.16 | 0.15 | 0.14 |
| Unsat Fat | 0.10 | 0.10 | 0.06 | 0.05 | 0.09  | 0.15 | 0.15 | 0.14 |
| Sat Fat   | 0.06 | 0.06 | 0.04 | 0.03 | 0.03  | 0.05 | 0.09 | 0.09 |
| Sodium    | 0.04 | 0.04 | 0.02 | 0.02 | 0.02  | 0.02 | 0.03 | 0.06 |
| Energy    | 0.04 | 0.04 | 0.02 | 0.02 | 0.02  | 0.02 | 0.01 | 0.03 |

From the above normalised matrix, row averages will be calculated which will serve as or weights (eigenvector) for parameters-

**Table 5.** Calculated Weights (eigenvector).

| Parameters      | Weights (eigenvector) | Weight Intensity (as per Table 2) |
|-----------------|-----------------------|-----------------------------------|
| Protein         | 0.26                  | Very High                         |
| Sugar           | 0.26                  | Very High                         |
| Magnesium       | 0.14                  | High                              |
| Zinc            | 0.12                  | High                              |
| Unsaturated Fat | 0.10                  | Medium                            |
| Sat Fat         | 0.05                  | Medium                            |
| Sodium          | 0.03                  | Low                               |
| Energy          | 0.03                  | Low                               |

In order to establish the consistency of the pairwise comparisons, multiplying the original matrix (A) by weight vector (w)-

**Table 6.** Calculated  $\lambda$  max.

| Parameters | $A \times w$ | $\lambda$ Values= $(A \times w)/\text{parameter weight}$ | $\lambda$ max=<br>Average of $\lambda$ Values |
|------------|--------------|----------------------------------------------------------|-----------------------------------------------|
| Protein    | 2.273714     | 8.592155                                                 | 8.39                                          |
| Sugar      | 2.273714     | 8.592155                                                 |                                               |
| Magnesium  | 1.201113     | 8.665049                                                 |                                               |

|                        |          |          |  |
|------------------------|----------|----------|--|
| <b>Zinc</b>            | 1.012561 | 8.491476 |  |
| <b>Unsaturated Fat</b> | 0.850455 | 8.29846  |  |
| <b>Sat Fat</b>         | 0.447784 | 8.18696  |  |
| <b>Sodium</b>          | 0.246751 | 8.07102  |  |
| <b>Energy</b>          | 0.20633  | 8.208726 |  |

Here number of parameter (n) =8. As per Saaty, (1977), for n=8, Random Index (RI)= 1.41

Thus, calculating consistency index (CI) =

$$\frac{\lambda_{\max} - RI}{RI - 1}$$

$$= \frac{8.39 - 1.41}{1.41 - 1}$$

$$= 0.06$$

Next, calculating consistency ratio (CR) =

$$\frac{CI}{RI}$$

$$= \frac{0.06}{1.41}$$

=0.04 approx.

Since  $0.04 < 0.10$ , it means the pairwise comparisons are consistent. Thus, it can be stated that the pairwise matrix generated in present research is logically coherent and not random making the judgement of researcher reliable.

## Sensory Evaluation

The granola samples have been evaluated for different sensory attributes with the help of 7 trained panellists. Before conducting the sensory assessment, ethical contemplations were duly addressed. All seven trained panellists were well-versed about the aim, procedures, and nature of the sensory assessment. The panellists were guaranteed that their contribution was voluntary. They were permitted to withdraw from the study at any stage without any penalties. Confidentiality and anonymity of participants were strictly maintained throughout the research. The sensory assessment involved negligible risk, as the granola formulations were prepared using food-grade ingredients under hygienic conditions suitable for human consumption.

The attributes like taste, colour, texture, appearance, aroma, and overall acceptability has been assessed for all samples using 9-point hedonic scale. The following is the sequence for 9-point hedonic scale: 9- Like Extremely, 8- Like Very Much, 7- Like Moderately, 6- Like Slightly, 5- Neither Like Nor Dislike, 4- Dislike Slightly, 3- Dislike Moderately, 2- Dislike Very Much, and 1- Dislike Extremely.

## RESULT AND DISCUSSION

The values received for nutritional parameters for fifteen formulations of Granola post lab testing are as below-

**Table 7.** Lab Test Values for the Fifteen Formulations of Granola.

| Formulation | Protein (g/100g) | Magnesium (mg/100g) | Zinc (mg/100g) | Unsaturated Fat (g/100g) | Energy (Kcal/100g) | Total Sugar (g/100g) | Saturated Fat (g/100g) | Sodium (mg/100g) |
|-------------|------------------|---------------------|----------------|--------------------------|--------------------|----------------------|------------------------|------------------|
| 1           | 14.6             | 165                 | 2.7            | 19.4                     | 472                | 12.4                 | 2.9                    | 96               |
| 2           | 15.8             | 158                 | 2.5            | 19                       | 469                | 11.8                 | 2.7                    | 88               |
| 3           | 12.3             | 172                 | 2.3            | 15.3                     | 455                | 13                   | 2.1                    | 75               |
| 4           | 13.5             | 168                 | 2.6            | 17.4                     | 460                | 12.6                 | 2.4                    | 84               |
| 5           | 16.7             | 174                 | 2.2            | 19.8                     | 478                | 11.1                 | 3                      | 99               |
| 6           | 17.5             | 160                 | 2.8            | 22.3                     | 490                | 12.3                 | 3.2                    | 102              |
| 7           | 12.9             | 155                 | 2.4            | 16.3                     | 452                | 12.9                 | 2.3                    | 78               |
| 8           | 14.2             | 170                 | 2.9            | 18.4                     | 465                | 11.8                 | 2.6                    | 80               |
| 9           | 16.2             | 162                 | 2.6            | 20.4                     | 485                | 10.6                 | 2.9                    | 95               |
| 10          | 14.9             | 150                 | 2.1            | 18.7                     | 468                | 12.2                 | 2.8                    | 87               |
| 11          | 18               | 188                 | 3              | 22.7                     | 491                | 10.4                 | 3.3                    | 104              |
| 12          | 14               | 176                 | 2.8            | 18.3                     | 466                | 11.5                 | 2.6                    | 81               |
| 13          | 14.8             | 182                 | 3.1            | 17.6                     | 463                | 11.9                 | 2.5                    | 83               |
| 14          | 15.3             | 169                 | 2.7            | 19.2                     | 471                | 11.7                 | 2.8                    | 89               |
| 15          | 12.1             | 157                 | 2.3            | 14.9                     | 450                | 13.2                 | 2                      | 72               |

Normalizing the above matrix-

**Table 8.** Normalizing the Lab Test Values for the Fifteen Formulations of Granola.

| Formulations | Normalized Mg | Normalized Zn | Normalized Unsaturated Fat | Normalized Energy | Normalized Total Sugar | Normalized Saturated Fat | Normalized Sodium |
|--------------|---------------|---------------|----------------------------|-------------------|------------------------|--------------------------|-------------------|
| 1            | 0.39          | 0.60          | 0.58                       | 0.46              | 0.29                   | 0.31                     | 0.25              |
| 2            | 0.21          | 0.40          | 0.53                       | 0.54              | 0.50                   | 0.46                     | 0.50              |
| 3            | 0.58          | 0.20          | 0.05                       | 0.88              | 0.07                   | 0.92                     | 0.91              |
| 4            | 0.47          | 0.50          | 0.32                       | 0.76              | 0.21                   | 0.69                     | 0.63              |
| 5            | 0.63          | 0.10          | 0.63                       | 0.32              | 0.75                   | 0.23                     | 0.16              |
| 6            | 0.26          | 0.70          | 0.95                       | 0.02              | 0.32                   | 0.08                     | 0.06              |
| 7            | 0.13          | 0.30          | 0.18                       | 0.95              | 0.11                   | 0.77                     | 0.81              |
| 8            | 0.53          | 0.8           | 0.45                       | 0.63              | 0.5                    | 0.54                     | 0.75              |

|    |      |     |      |      |      |      |      |
|----|------|-----|------|------|------|------|------|
| 9  | 0.32 | 0.5 | 0.71 | 0.15 | 0.93 | 0.31 | 0.28 |
| 10 | 0.00 | 0   | 0.49 | 0.56 | 0.36 | 0.38 | 0.53 |
| 11 | 1.00 | 0.9 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| 12 | 0.68 | 0.7 | 0.44 | 0.61 | 0.61 | 0.54 | 0.72 |
| 13 | 0.84 | 1   | 0.35 | 0.68 | 0.46 | 0.62 | 0.66 |
| 14 | 0.50 | 0.6 | 0.55 | 0.49 | 0.54 | 0.38 | 0.47 |
| 15 | 0.18 | 0.2 | 0.00 | 1.00 | 0.00 | 1.00 | 1.00 |

Using the assigned weights (Table 5), computing the composite score by using the following formula- (Normalized Protein \* 0.26)+(Normalized total sugar \* 0.26)+(Normalized Mg \* 0.14)+(Normalized Zn \* 0.12)+(Normalized Unsaturated Fats \* 0.10)+( Normalized Saturated Fats \* 0.05)+(Normalized Na \* 0.03)+(Normalized Energy\*0.03)

Applying the above formula on all the fifteen formulations in Table 8 to calculate composite score-

**Table 9.** Composite Score and Corresponding Ranking for Fifteen Formulations of Granola.

| Formulations | Composite Score | Rank |
|--------------|-----------------|------|
| 1            | 0.41            | 10   |
| 2            | 0.48            | 9    |
| 3            | 0.25            | 13   |
| 4            | 0.36            | 11   |
| 5            | 0.59            | 4    |
| 6            | 0.54            | 8    |
| 7            | 0.24            | 14   |
| 8            | 0.51            | 6    |
| 9            | 0.63            | 3    |
| 10           | 0.32            | 12   |
| 11           | 0.87            | 1    |
| 12           | 0.54            | 5    |
| 13           | 0.59            | 2    |
| 14           | 0.53            | 7    |
| 15           | 0.17            | 15   |

Thus, the formulation with highest composite score is given the rank one and formulation with lowest composite score is given the last rank. Formulation 11 has been ranked 1 and is thus the best formulation for management of PCOS.

Once formulation 11 was identified as the best formulation for PCOS management, its sensory test was also conducted with the help of 7 highly trained panellists. The panellists judged the formulation on attribute namely taste, colour, texture, appearance, aroma, and overall acceptability. The results are as below-

**Table 10.** Mean Results for Sensory Evaluation of Formulation 11.

|                       | Taste | Color | Texture | Appearance | Aroma | Overall Acceptability |
|-----------------------|-------|-------|---------|------------|-------|-----------------------|
| <b>Mean</b>           | 8.14  | 7.86  | 7.57    | 8.00       | 8.14  | 8.14                  |
| <b>Std. Deviation</b> | .690  | .690  | .535    | .577       | .690  | .690                  |

The mean values of all the attributes are above 7 where 9- Like extremely, 8- Like Very Much, 7- Like Moderately. This means that the expert panellists rated formulation 11 on positive note. As inferred from Table 10, experts liked the taste, Appearance, Aroma and Overall Acceptability very much. Further, Texture and Color of formulation 11 were moderately liked by the experts.

The graphical representation of the frequency distribution of sensory evaluation parameters have been presented below-

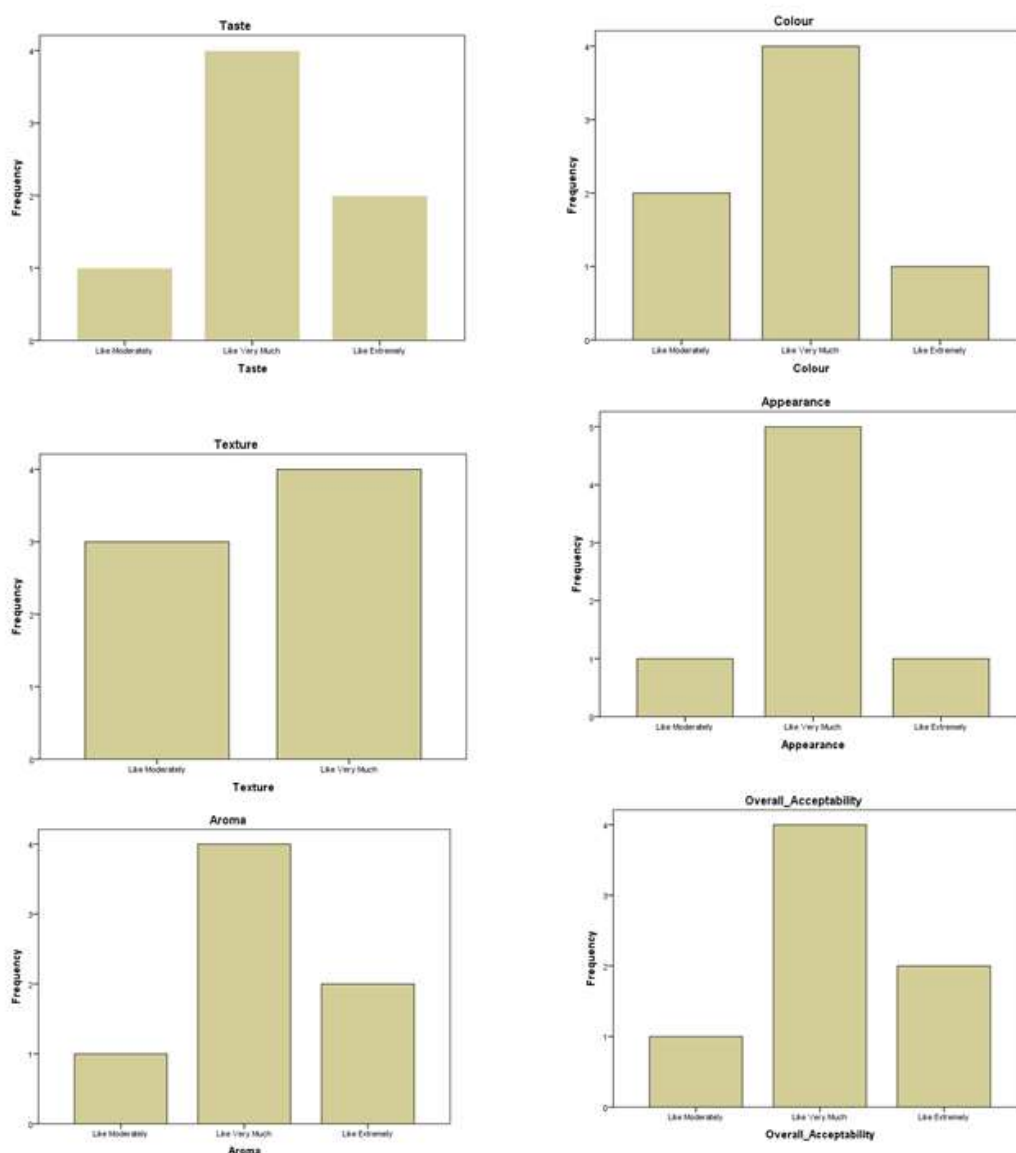


**Figure 1.** Frequency Distribution for Sensory Evaluation.

## DISCUSSION

Post conducting MCDM on the nutrition parameter values of fifteen formulations (collected from lab), formulation 11 has been identified as the most nutritionally appropriate cinnamon-based polyherbal granola for the management of polycystic ovarian disorder (PCOS). This finding is based on superior composite nutritional score of formulation 11 derived through AHP-weighted multi-criteria evaluation. It revealed a good equilibrium of macronutrients and micronutrients unswervingly appropriate to insulin resistance, inflammation, and hormonal deregulation. These are the chief pathophysiological aspects for management of PCOS (Teede et al., 2018).

One of the best significant parameter was its lowermost total sugar content. Elevated dietary sugar consumption aggravates hyper-insulinemia, which arouses ovarian androgen creation and deteriorates PCOS indicators (Diamanti-Kandarakis & Dunaif, 2012). Diets with measured sugar intensities are related with better glycaemic reaction and menstrual uniformity in women with PCOS (Moran et al., 2013). Therefore, the decreased sugar profile of Formulation 11 supports metabolic steadiness.

Formulation 11 also had the maximum protein content among all formulations. High-protein diets improve satiety, decrease postprandial glucose excursions, and develop insulin sensitivity. These positives are predominantly significant in PCOS management (Juhász et al., 2024). Augmented protein consumption has also been related with better weight regulation and decreased androgen altitudes (Che et al., 2021).

The formulation displayed the highest magnesium content. Magnesium plays an essential role in glucose metabolism and insulin signalling passageways. Its deficiency has been associated with increased insulin resistance and systemic inflammation (Barbagallo & Dominguez, 20015). Magnesium supplementation has established improvements in metabolic indicators in women with PCOS (Shahmoradi et al., 2024b)

Furthermore, it's raised zinc content backs reproductive and endocrine health. Zinc effects ovarian utility and decreases oxidative stress, which is recurrently raised in PCOS (Camp et al., 2025). Acceptable zinc consumption has been connected with developments in hirsutism and hormonal equilibrium.

From a lipid viewpoint, Formulation 11 presented the maximum unsaturated fat content with controlled saturated fat levels. Unsaturated fats, predominantly monounsaturated and polyunsaturated fatty acids, progress lipid profile, decrease inflammation, and improve insulin sensitivity (Chen et al., 2023). In contrast, increased saturated fat consumption is related with metabolic dysfunction and inflammatory paths (Grosso et al., 2022). The positive lipid ratio in Formulation 11 donates to its anti-inflammatory and cardio-metabolic benefits.

Even though energy density was reasonably high, granola is characteristically consumed in portion-controlled servings, making complete caloric influence controllable inside dietary development structures for PCOS (Moran et al., 2013). Sodium levels endured within adequate restrictions and do not unswervingly effect PCOS pathophysiology, though moderation supports cardiovascular risk management.

Significantly, the presence of cinnamon and polyherbal constituents further improves metabolic prospective. Cinnamon has been revealed to progress insulin sensitivity and menstrual cycle in women suffering from PCOS (Kumar et al., 2023). Its bioactive combinations improve glucose in body and decrease oxidative stress.

Together, the greater macronutrient equilibrium, ideal micronutrient concentration, and complimentary lipid profile are the reasons for Formulation 11 having being accomplished the maximum composite score. The incorporation of insulin-regulating nutrients, anti-inflammatory fats, and endocrine-supportive minerals marks it above all and most appropriate as a functional food intervention for PCOS management when compared to other formulations considered in the present research.

Sensory acceptability is a critical determinant of the success of functional foods. As a matter of fact, nutritional superiority alone does not ensure consumer adoption (Drake et al., 2023). In the present study, Formulation 11 also demonstrated high sensory acceptance across all evaluated attributes when assessed by seven trained panelists using a 9-point hedonic scale.

The mean scores for all features were above 7.5, representing that the preparation was generally rated between “Like Moderately” and “Like Extremely.” Taste received predominantly very high scores owing to the well-adjusted sugariness profile and the presence of cinnamon. Cinnamon is known to facilitate in glycemic control and drastically improve taste. Since cinnamon has perceived natural sweetness, it facilitates in decreasing the added sugar without negotiating the deliciousness (Majeed et al., 2025). This is vital in PCOS-targeted nourishments where sugar lessening is essential but flavor must continue to be conventional.

Aroma also scored one of the highest score, reflecting the sensory involvement of polyherbal constituents and crisped cereal aspects. These constituents are known to improve product appeal and attractiveness.

Color and appearance were evaluated to be steadily high, demonstrating even baking and optical attractiveness. Visual features are often the chief determining factor of product recognition and approval from the side of consumers. As a matter of fact, it influences general perception before tasting (Drake et al., 2023). Prominently, complete acceptability carefully associated with taste and aroma scores, strengthens the role of taste outline in determining consumer acceptance.

Texture was also regarded positively but was less when compared to other sensory parameters. This shows presence of suitable crustiness, firmness and textured. These are important characteristics that suggestively impact granola appropriateness (Lawless & Heymann, 2010). The existence of nuts, seeds, and measured fat configuration possibly backed the promising textural perception.

Together, the sensory outcomes approve that nutritional optimization did not hindered the deliciousness. Functional food progress necessitates coordinating health benefits with sensory charm (Granato et al., 2020). Formulation 11 effectively attained this balance, backing its appropriateness as a dietary intervention for PCOS management which is acceptable by consumers.

## CONCLUSION

The present research on development and nutritional profiling of cinnamon-based polyherbal granola for management of PCOS has successfully developed the best fit formulation out of all the formulations considered in this research. Among the fifteen formulations developed, **Formulation 11** presented the higher nutritional quality, having low sugar content, better protein presence, higher magnesium and zinc concentrations, and a promising unsaturated fat profile. These nutritional characteristics are closely associated with evidence-based dietary endorsements for refining insulin sensitivity, dropping redness, and associating hormonal balance in PCOS. The implementation of the Analytic Hierarchy Process (AHP) delivered a systematic and methodically authorized method for multi-criteria nutritional ranking, approving the strength of formulation.

Notably, sensory valuation showed high appropriateness across taste, aroma, texture, color, and overall preference. This shows that nutritional optimization did not impact the deliciousness. The incorporation of metabolic usability with consumer appropriateness, the strength the Formulation 11 as a functional food intervention for PCOS is strong.

Largely, the present research shows the possibility of evolving nutrient-dense, sensory-acceptable cereal-based produces that may add to nutritional approaches for PCOS management. Moreover, the clinical authentication is suggested to validate long-term metabolic and hormonal aids.

The current research facilitates in the advancement of a condition-specific, cinnamon-based polyherbal granola designed to take care of key metabolic and micronutrient concerns in women with PCOS. By applying a structured MCDM approach, it validates an evidence-based approach for optimizing functional food formulations aligned with metabolic health aims. The outcomes support the role of targeted dietary interventions in precautionary healthcare and deliver groundwork for future clinical validation via randomized controlled trials.

In terms of limitations, glycemic index was not measured experimentally. Also, metabolic functionality is inferred rather than directly tested. Also, only fifteen formulations were tested, potentially limiting formulation optimization and no consumer acceptability testing across different age or demographic groups was conducted.

Even though the current research establishes favorable nutritional and sensory results, clinical efficacy has not yet been established. Therefore, a Randomized Controlled Trial (RCT) is proposed as a future scope of this research. This will scientifically assess the therapeutic efficiency of the developed cinnamon-based polyherbal granola in women with PCOS.

The proposed RCT would focus on to assess its impact on key clinical and metabolic factors like insulin resistance, hormonal profile, inflammatory markers and menstrual regularity to name a few. Conducting a well-designed RCT with an suitable sample size would deliver vigorous indication concerning the product's safety, efficacy, and long-term benefits in PCOS management.

## Acknowledgement

The authors gratefully acknowledge Galgotias University for providing GU Fellowship, academic support and access to resources that facilitated the completion of this review. We also extend our appreciation to the faculty and peers who provided constructive insights throughout the research process.

## Funding Information

The authors declare that GU Fellowship was received for conducting this study.

## Conflict of Interest Statement

The authors declare **no conflict of interest** related to the publication of this manuscript.

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