iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VI **Month of publication:** June 2026

DOI: https://doi.org/10.22214/ijraset.2026.83353

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

Formulation, Optimization and Physicochemical Evaluation of a Whole Lemon Spice Powder

Prof. Divya Korde[1], Dr. Prashant Watkar[2], Diksha Gadekar[3], Aishwarya Teltumbade[4], Sneha Mankar[5]
[1, 2]*Assistant Professor, Department of Food Technology, BIT Ballarpur, Maharashtra*
[3, 4, 5]*Research Scholar, Department of Food Technology, BIT Ballarpur, Maharashtra*

Abstract: ***This study presents the development and comprehensive evaluation of Whole Lemon Powder (WLP), a novel functional food ingredient produced by drying and grinding the entire Citrus limon fruit, including both peel and pulp. The research promotes sustainability by utilizing lemon peel, a major source of agricultural waste, thereby reducing environmental impact while enriching the nutritional profile of the final product. Analytical results revealed that WLP is a concentrated source of dietary fiber, pectin, and bioactive compounds such as phenolics and flavonoids, contributing to a significantly higher antioxidant capacity compared to conventional lemon juice powder. The processing method involved tray drying at 50°C, a temperature optimized to preserve nutritional integrity, aromatic components, and overall product stability. Proximate analysis was also done to check the protein content , fat content , total ash content , carbohydrate content , fiber content and sensory evaluations verified the functional and sensory suitability of the powder. Among the tested formulations, WLP-4 achieved the highest consumer acceptance, obtaining a score of 9.0 for taste, appearance, and mouthfeel. These results confirm that WLP delivers strong sensory appeal alongside enhanced functional benefits while supporting a zero-waste production approach. Overall, this study establishes Whole Lemon Powder as a shelf-stable, nutrient-rich, and environmentally sustainable ingredient with promising applications in the nutraceutical, beverage, and food industries. Its intense natural lemon flavor, elevated antioxidant activity, and clean-label characteristics make it an excellent candidate for product innovation and functional food development. It contain 0.28% ash, 0.01% moisture, 0.73% fat, 7.90% protein, 11.83% fiber, and 79.25% carbohydrates.***
Keywords: Whole lemon powder, Citrus limon, functional food ingredient, sustainability, antioxidant activity, dietary fiber, phenolic compounds, tray drying, sensory evaluation, zerowaste processing, protein, fat, ash ,carbohydrate.

I. INTRODUCTION

Citrus fruits are among the most widely cultivated and commercially important fruits in the world due to their nutritional value, refreshing flavor, and health-promoting properties. They belong to the family Rutaceae and include fruits such as orange, lemon, lime, grapefruit, and mandarin. Among them, lemon (Citrus limon L.) is highly valued for its acidic juice, characteristic aroma, and abundance of bioactive compounds. Lemon is extensively used in food processing industries for the production of juices, concentrates, beverages, bakery products, flavoring agents, and nutraceutical formulations. During processing, a significant quantity of by-products such as peel, pulp, and seeds is generated, with lemon peel alone accounting for nearly 50–65% of the total fruit weight. These by-products are generally discarded as waste, causing environmental pollution and microbial spoilage problems. However, recent studies have shown that lemon peel and other citrus by-products are rich sources of valuable phytochemicals, including flavonoids, phenolic compounds, dietary fiber, pectin, essential oils, and vitamin C, which possess strong antioxidant, antimicrobial, anti-inflammatory, and health-promoting properties.

Whole lemon powder is produced by drying and grinding the complete lemon fruit, including peel, pulp, and juice vesicles, into a fine powder. Unlike conventional lemon juice powder, whole lemon powder retains the functional components present in the peel, making it nutritionally superior and more beneficial for food applications. Research has demonstrated that lemon peel contains significantly higher concentrations of antioxidant compounds compared to lemon juice. The major phenolic constituents present in lemon include flavanones, flavonols, flavones, ferulic acid, p-coumaric acid, and sinapic acid, which contribute to antioxidant activity and protection against oxidative stress. In addition, lemon peel is an excellent source of pectin and insoluble dietary fiber, which improve water-holding capacity, viscosity, texture, and stability in formulated food products. Essential oils such as d-limonene present in lemon peel also exhibit antimicrobial activity against spoilage and pathogenic microorganisms, thereby enhancing food preservation and shelf life.

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The method used for drying plays a crucial role in determining the quality, nutrient retention, and storage stability of whole lemon powder. Drying reduces moisture content and water activity, thereby preventing microbial growth and extending shelf life. Common drying techniques used in lemon powder production include spray drying, tray drying, hot-air drying, and freeze drying. Spray drying is widely used for industrial production due to its cost-effectiveness and rapid processing; however, exposure to high temperature may lead to degradation of heat-sensitive nutrients such as vitamin C. Freeze drying, on the other hand, retains higher amounts of bioactive compounds, flavor compounds, and antioxidant activity, although it involves higher processing costs. Proper drying and packaging help maintain acidity, flavor, color, and nutritional quality of the powder during storage.

Whole lemon powder has gained increasing attention in recent years because of its multifunctional properties and wide industrial applications. It is extensively used in beverages, bakery products, confectionery items, sauces, snack seasonings, instant soups, nutraceutical supplements, and cosmetic products due to its natural flavor, acidity, antioxidant potential, and preservative effects. In bakery products, the fiber and pectin content improve texture and moisture retention, while in beverage systems it enhances viscosity and stability. The powder also serves as a natural source of vitamin C and bioactive compounds in functional food development. Furthermore, utilization of whole lemon for powder production supports sustainable and zero-waste food processing approaches by converting citrus waste into value-added products. This not only provides economic benefits to the food industry but also helps reduce environmental pollution associated with disposal of citrus processing by-products. Therefore, whole lemon powder is considered a promising functional ingredient with significant nutritional, technological, and commercial importance in modern food systems.

II. MATERIAL AND METHODOLOGY

This chapter contains all the materials and methodology followed to prepare and test the product. The test methods for testing raw materials and products are also discussed. Research work was carried out at the Department of food Technology, Ballarpur Institute of Technology ,Ballarpur.

A. Material Required For Research Study

Materials	Weight
Dried lemon powder	5 gm
Turmeric powder	0.50 gm
Cumin powder	1 gm
Powdered sugar	2 gm
Salt	3 gm
Coriander powder	2 gm

B. Selection of Lemon Plant Species

The following investigations will be conducted on the whole lemon powder(citrus limon) that were selected as the main ingredients for the study.

C. Collection And Extraction

1) Collection

Fresh lemon (citrus limon) collected from Chandrapur district , Maharashtra , for the preparation of the respective powder.



(a) fresh lemon (b) dried lemon

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2) Grinding

Grinding of Dried Lemon

Dried lemon were used for the preparation of lemon powder. The fresh lemon were cleaned manually to remove dust, dirt and visible foreign particle. After cleaning, the fresh lemon were cut into slices and remove the seed to reduce bitterness of lemon. This process reduce the moisture of lemon slice. The temperature of tray dryer at 50 º c for 24 hrs. It minimize the moisture of fresh lemon or convert into dried form .After drying , grind the dried lemon into fine powder by using grinder. The dried powder was sieved to achieve uniform fine texture. Coarse particles retained on the sieve were re-ground to minimize loss. The final horse gram flour was stored in an airtight container to protect it from moisture and maintain its quality.

Flowchart:-

RAW MATERIAL
↓
WASHING(REMOVALOFIMPURITIES)
↓
CUTTING
↓
SEED REMOVAL
↓
TRAY DRYER (50ºC FOR 24HRS)
↓
COOLING
↓
STORAGE

Procedure

- Fresh and clean raw materials are selected to ensure good quality and safety, as damaged or over-ripe produce can affect taste and shelf life. The produce is washed properly to remove dirt, dust, microorganisms, and pesticide residues.
- It is then cut into equal-sized pieces for uniform and faster drying, and seeds are removed to avoid bitterness and excess moisture retention. The pieces are tray dried at 50°C for 24 hours to safely reduce moisture while maintaining nutrients, color, and flavor.
- After drying, the product is cooled to room temperature to prevent moisture condensation inside the package. Finally, it is stored in airtight, moisture-proof packaging in a cool and dry place to maintain quality and extend shelf life.

D. Preparation of whole lemon powder

The standard whole lemon powder preparation method was followed with slight modifications based on blend that combines tanginess with balanced spices to create a stable, easy-to-use seasoning for snacks and food preparations. After several trials and sensory observations, the proportions of whole lemon powder .

Raw materials

Dried lemon powder , sugar ,salt , cumin powder ,coriander powder

Preparation of whole lemon powder

Different proportions of both the dried lemon powder and other ingredients were taken and several batches of whole lemon powder were prepared to obtain the desired texture and taste. Various ratios were standardized, and the best proportion was selected based on sensory analysis results.

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Flowchart :-

TAKE 5GM OF DRIED LEMON POWDER
↓
WEIGHT ALL INGREDIENT
↓
ADDED INGREDIENTS (POWDERED SUGAR,CUMIN POWDER, CORIANDER POWDER,SALT)
↓
GRINDING
↓
SIEVING
↓
PACKAGING
↓
STORAGE

1) Weighing of Ingredients
Ingredients were taken as per different combinations in each trial.

- 100% dried lemon powder + 10 % salt , 10 % sugar , 10 % cumin powder,10 % coriander powder , 0.50 % turmeric
- 100% dried lemon powder +20 % salt , 20 % sugar , 20 % cumin powder , 20 % coriander powder , 0.50 % turmeric
- 100% dried lemon powder +20 % salt , 30 % sugar , 20 % cumin powder , 30 % coriander powder , 0.50 % turmeric 25

2) Add Ingredients to Lemon Powder: Combine all the measured powders with the lemon powder to form a uniform premix.
3) Grinding: Grind the mixture briefly to ensure even particle size and proper blending without causing heat buildup.
4) Sieving:-Pass the ground blend through a fine mesh sieve to remove lumps and achieve a smooth, uniform powder.
5) Packaging:- Fill the powder into moisture-proof pouches and seal immediately to prevent moisture absorption and clumping.
6) Storage :-Store in a cool, dry place away from direct light to maintain flavor and shelf stability.

III. RESULT AND DISCUSSION

A. Product Development

Sensory evaluation of the prepared product was done based on six parameters: Taste, Appearance , Aroma, Mouth feel, colour, Overall acceptance.

Sample Code	Taste	Appearance	Aroma	Mouth Feel	Colour	Overall Acceptance
WLP 1	6±1	7±0.54	7±0.54	6±0.89	7±0.44	6±0.89
WLP 2	7±0	7±0	6±0.44	6±0.44	7±0	7±0
WLP 3	6±0.54	6±0.44	6±0.54	6±0.44	6±0.54	6±0.44
WLP 4	9±0	9±0	8±0.54	9±0	9±0	9±0
WLP 5	6±0.54	6±0.54	7±0	6±0.54	7±0	7±0
WLP 6	7±0.70	8±0.54	8±0.54	7±0.70	8±0.44	8±0.44
WLP 7	6±0.89	6±0.54	6±0	6±0.04	6±0.54	6±0.89
WLP 8	6±0.83	6±0.54	5±0.83	5±1.14	5±1.14	5±1.14

Sensory analysis of prepared whole lemon powder

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Sensory analysis sample whole lemon powder

1) Proximate analysis result of whole lemon powder

Factors / parameters (%)	Results
Moisture content	0.01
Ash content	0.28
Crude fat	0.73 %
Protein content	7.90 %
pH content	3.83
Crude fiber	11.83 %
Carbohydrates	79.25 %

Table :-Proximate analysis result table

2) Microbial analysis of whole lemon powder

Factors/ parameters	Result
Escherchia coli	Absent
Salmonella	Absent
Total plate count	8.9×10^2cfu/g

Table **:-** Microbial analysis result table

B. Sensory Analysis

- A 9 Pointer hedonic scale was used to do sensory analysis.
- 6 different samples of different proportions were prepared.
- 7 panelists gave their different judgments over the parameters.
- Parameter for sensory analysis – Taste, Appearance, Aroma, Mouth feel, Colour, and overall acceptance.


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SENSORY EVALUATION

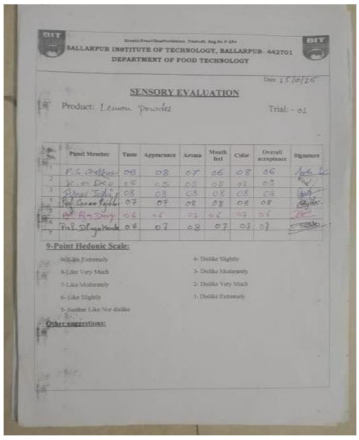
Product: Trial: -

Sr. No.	Panel Member	Taste	Appearance	Aroma	Mouth feel	Color	Overall acceptance	Signature
1								
2								
3								
4								
5								
6								
7								

9-Point Hedonic Scale:

Other suggestions:

Sample copy of sensory evaluation

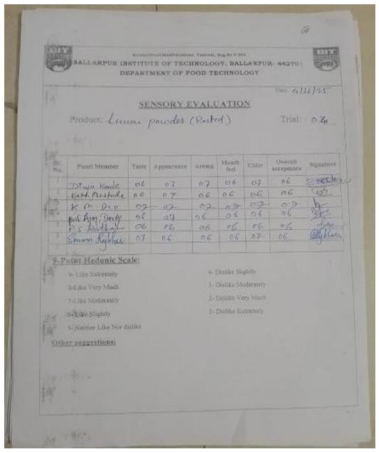

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SENSORY EVALUATION

Product: Lemon powder Trial: - 01

9-Point Hedonic Scale:

Other suggestions:

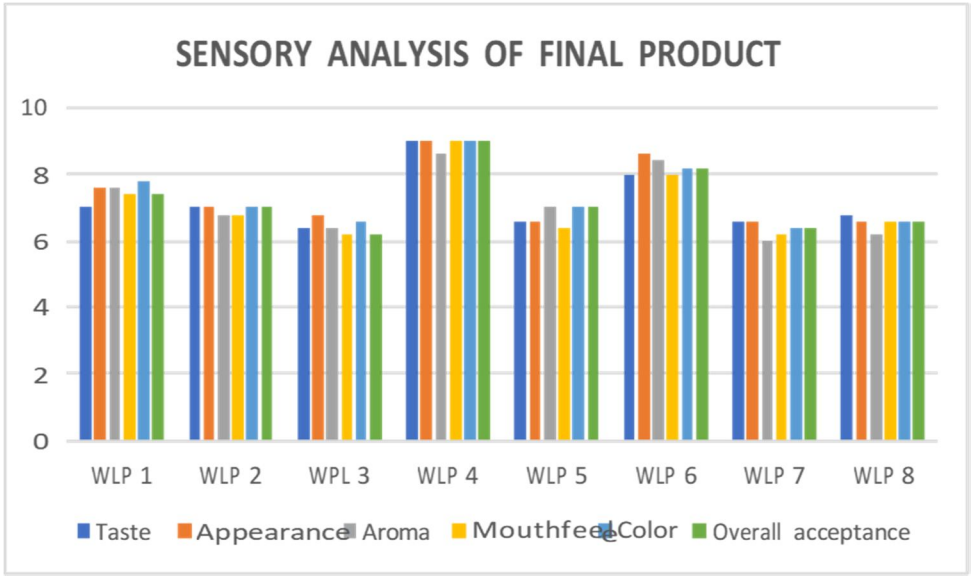

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SENSORY EVALUATION

Product: Lemon powder (Roasted) Trial: - 02

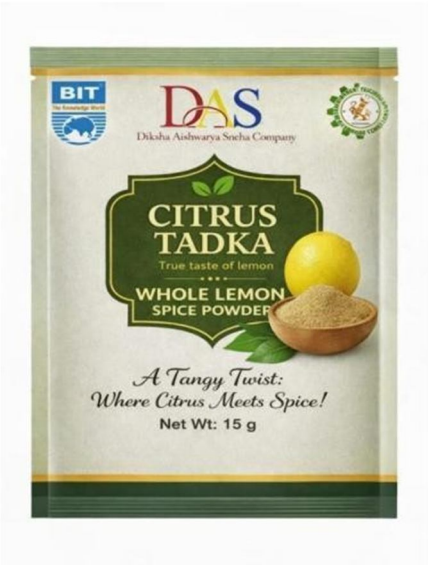
9-Point Hedonic Scale:

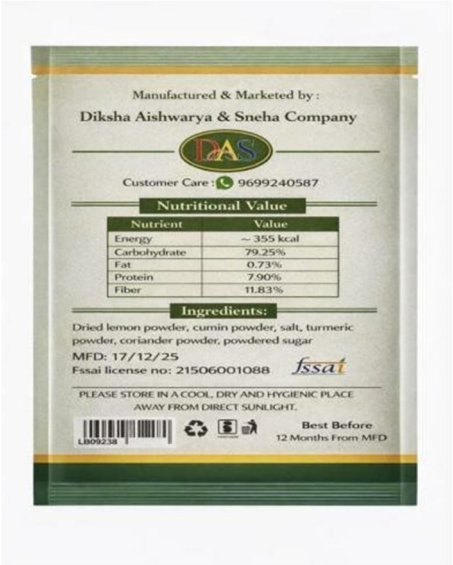
Other suggestions:



Graphical representation of sensory evaluation

C. Final product





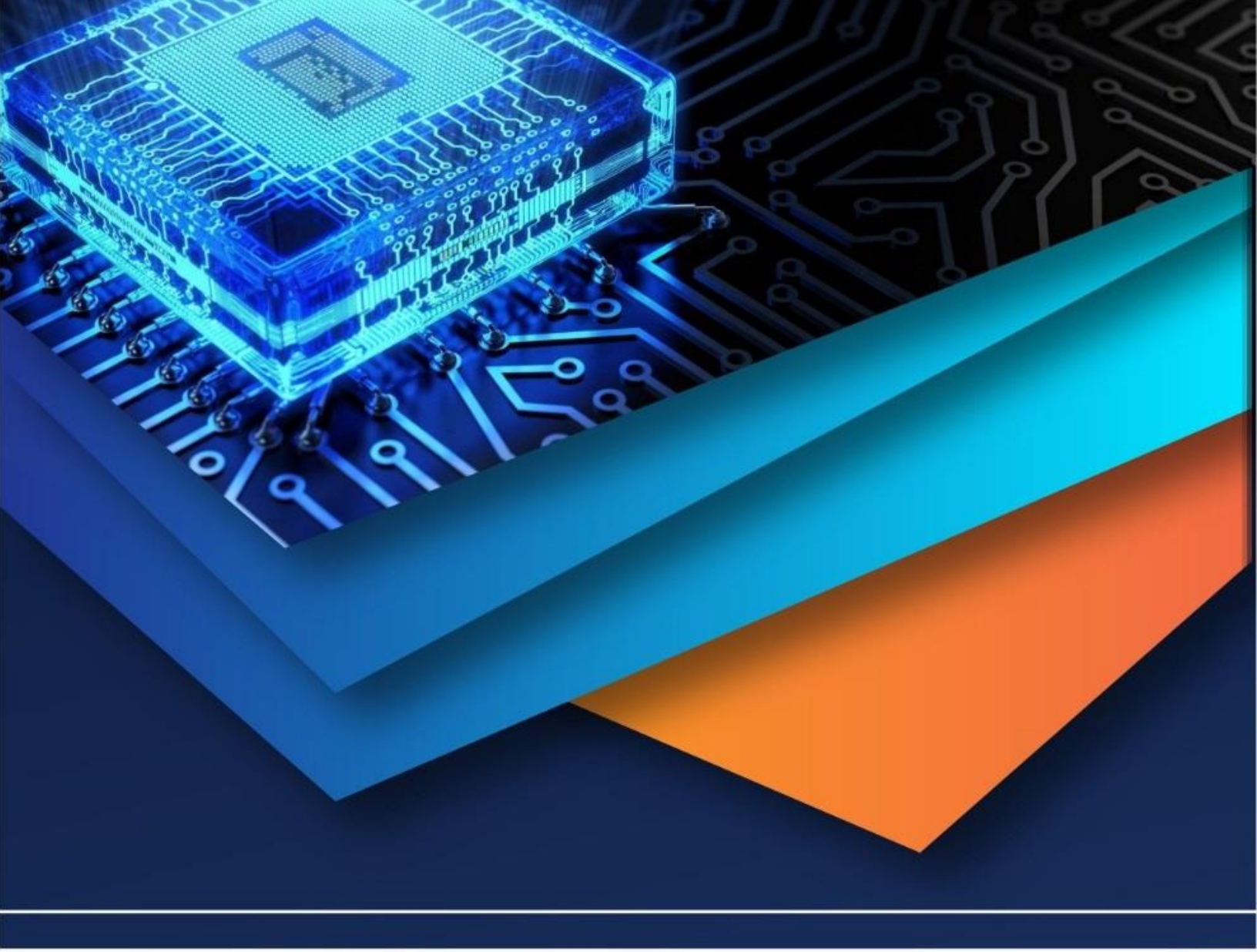
IV. CONCLUSION

The developed Whole Lemon Powder (WLP) is a nutritionally superior, sustainable, and highly marketable functional food ingredient. This was achieved by successfully processing the entire Citrus limon fruit—including the typically discarded peel—which significantly boosted the powder's health profile. Specifically, the retention of the peel's compounds resulted in a potent concentration of dietary fiber, pectin, and powerful antioxidants (phenolics and flavonoids), far exceeding the nutritional value of standard lemon juice powder. The optimal production method involved tray drying at 50°C, ensuring excellent stability and long shelf-life. Crucially, Sensory Analysis confirmed its high commercial viability, with the best formulation (WLP-4) achieving an outstanding score of 9.0 in overall acceptability, making the product an ideal natural fortifier and flavor enhancer for use in nutraceuticals, beverages, and the wider food industry. Whole lemon powder represents a highly valuable ingredient due to its concentrated flavor, extended shelf life, and retention of the full nutritional profile of fresh lemons. By utilizing the entire fruit—including the peel, pulp, and juice—it provides a rich source of vitamin C, antioxidants, essential oils, and dietary fiber. Its natural acidity and aromatic compounds contribute bright, citrusy notes that enhance both sweet and savory formulations. Beyond flavor enhancement, whole lemon powder offers functional benefits such as acting as a natural preservative, improving product stability, and delivering consistent taste without the variability of fresh produce. Its ease of storage, transport, and incorporation into dry blends or processed foods makes it ideal for large-scale food manufacturing as well as household culinary use. Overall, whole lemon powder is a cost-effective, versatile, and nutrient-dense ingredient that supports product innovation, improves sensory qualities, and meets consumer demand for natural, clean-label components.

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