REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org

Development And Evaluation Of Instant Soup Mix Utilizing Leftover Hydrodistilled Orange Peel Flour

Priti Dongre* [1,2], Shaily Chaudhary[2], Naveen Gupta[2], Dharmendra Singh Rajput[2], Chandrashekhar Doifode[1]

[1*]Shri Sachhidanand Shikshan Sanstha's Taywade College of Pharmacy Koradi, Nagpur, Maharashtra, India 441111.
[2]Patel College of Pharmacy, Madhyanchal Professional University, Ratibad, Bhopal, Madhya Pradesh, India 462044.

***Corresponding Author:** Priti Dongre
[*]Shri Sachhidanand Shikshan Sanstha's Taywade College of Pharmacy Koradi, Nagpur, Maharashtra, India 441111.
9766778927, Email: pritidongrengp@gmail.com

Abstract
Lifestyle habits as well as nutrition are crucial factors that affect the quality of life. Globally,people are adopting healthier diets to avoid lifestyle related health issues and for that they aredependant onprocessed food to meet their basic dietary needs.Instant soup mixes with high nutritive value are becoming more popular as they are processed, ready to cook and take less time withless effort in preparation. In the present study,leftover hydrodistilled orange peel flour was used as the base ingredient to formulate the soupmix. This industrial waste residueneeds to be utilized in food products as it contains essential micro and macronutrientswith essential amino acids. The developed soup product was further evaluated for nutritional content, sensory, functional properties and shelf life to confirm consumer acceptability.A study revealed that a soup mixloaded with dietary fibres, micro and macronutrientscan provide recommended daily nutrients. Sensory evaluation and functional properties confirmed the significant acceptance level.No microbial growth was observed in the soup mix during storage period of one month at room temperature. The developed soup product resulted in healthy friendly product with good nutritional content and maximum health benefits. Theleftover hydrodistilled orange peel and additivesin the form of nutritive soup products could provide basic dietary needs and this soup product can get applicability in the neutraceutical and food industry as a value added functional food ingredient.

Introduction
Lifestyle habits as well as nutrition are very important factors that affect the quality of life.Nowadays lay-people also seek food products that provide maximum health benefits [1]. People residing in urban areas adopt healthier diets to avoid lifestyle related health issues and for that they depend on packaged food to meet their daily nutritional demands[2]. Soups are one of the best packaged food products gaining popularity as a health-friendly products and is good option for people who prioritize their health[3]. Soups are served as a delicious healthy side dish, starters or appetizer loaded with fibers, macro and micro-nutrients[4]. Nutritional aspects of soup food products and their relation to future health have also become particularly important for manufacturers and buyers [5]. Revenue in the Soups market amounts to US$ 0.75bn in 2024. The market is expected to grow annually by 6.96% (CAGR 2024-2029) [6].
In the present study,the soup product is prepared from leftover hydrodistilled peels of *Citrus sinensis*(orange) that remained after essential oil extraction. Citrus essential oil industries after oil extraction just dumped the leftover hydrodistilled residue on adjacent land. This led to environmental pollution and subsequently ecosystem degradation. As the world strives to achieve the Sustainable Development Goals by 2030, fight environmental pollution and natural resource scarcity, these industries are heading the opposite way generating significant amounts of waste [7]. An earlier investigation found that leftover hydrodistilled peels of *C. sinensis* had antidiabetic and antioxidant properties [8]. This prepared soup product from left-over hydrodistilled peels has important nutritional characteristics and is novel to hold good commercial potential.

To the best of our knowledge, studies on leftover hydrodistilled peels of *Citrus sinensis* are yet to be explored. The main objective of the present study is to examine the potential of the leftover hydrodistilled orange peel (LHOP) generated by the citrus essential oil industry and investigate the nutritional content and further development of soup formulation.

Materials and Methods
Orange Peels Collection: Waste orange peels were collected from farmers of Nagpur district, Maharashtra, India. Finger millet, salt purchased from local market. Dehydrated onion powder, garlic, tomato, ginger powder is provided by MGK Food and Naturals PVT LTD, Nagpur, Maharashtra, India. Fresh Stevia leaves were collected from the institute herbal garden, dried and powdered. All the chemicals used in the study were analytical grade purchased from S.D. Fine Mumbai, India.

Preparation of leftover hydrodistilled orange peels (LHOP) Flour

Orange peels were thoroughly washed, cut into small pieces followed by sunlight drying for 3 days and finally ground into fine powder using domestic mixer.For LHOP residue, hydrodistillation was carried out using a clavenger apparatus at 70ºC for 3 hrs. Essential oil industries use the same procedure to extract essential oil and ignore the leftover residue. In the present study, leftover residue remained in RBF after oil extraction was processed further. Obtained LHOP residue was filtered, dried using rotary vaccum evaporator at 40ºC and then spray dried to obtain dry free flowing flour (Fig.1). The Prepared LHOP flour stored in refrigerator for further formulation and analysis.

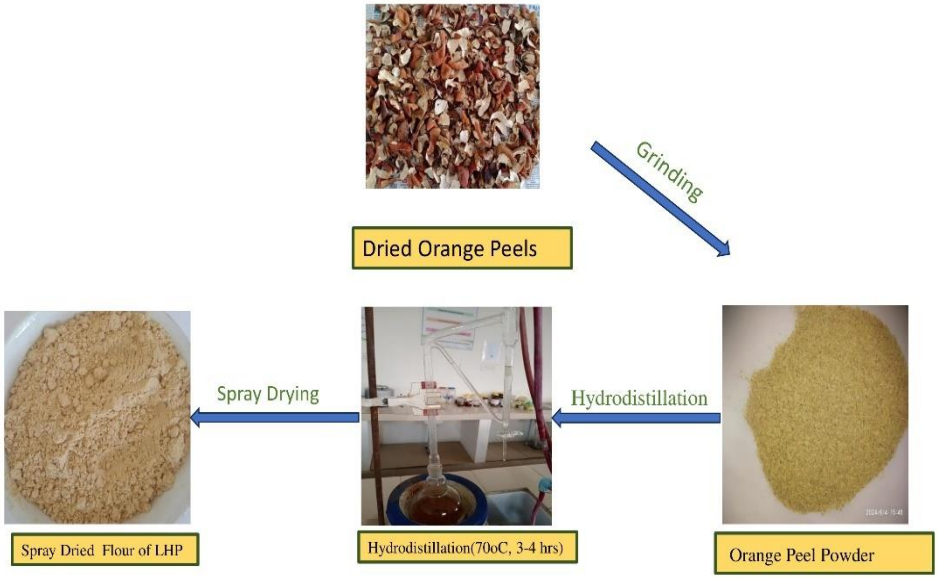

Fig 1. Preparation of Leftover HydrodistilledOrange Peel Flour

Nutrient ContentAnalysis of Leftover HydrodistilledOrange Peel (LHOP)Flour

Interest was taken in the nutritional content present in LHOP residue so that in this form it can be used to develop a value-added product with maximum health benefits. The nutritional composition of leftover hydrodistilled peels was analyzed using standard AOAC methods.The protein was analyzed using the Kjeldahl method as mentioned by AOAC 992.23. Total fat content was determined after acid hydrolysis and solvent extraction using the Soxhlet™ apparatus as mentioned by AOAC 992.06. The total carbohydrate content was determined according to the method of McCseady (1970) and Dubois et al. (1956).

Dietary fiber was analyzed using the enzymatic gravimetric method as mentioned by AOAC 985.29. Ash content was determined by heating a sample in a muffle at 550 ◦C as mentioned by AOAC 945.46. Moisture content was measured by drying a sample in a hot-air oven at 105 ◦C as mentioned by AOAC 927.05 [9]. After analyzing the leftover hydrodistilled peel flour, results confirmed that prepared LHOP flour contains an appreciable amount of nutritional content and minerals. It can be used to prepare value-added product to get applicability in food, neutraceutical and pharmaceutical industries rather than going waste.

Formulation And Ready To Eat Soup Development

Preliminary trials were conducted to formulateLHOP soup mix. Different compositions of all the ingredients finger millet, onion, tomato, ginger, and garlic were tried, reconstituted in hot water and evaluated for sensory. Staviawas added to mask the bitter taste of LHOP flour. Consistency, flavour and amount of water required for reconstitution of soup mix were determined by repeated trials and panel suggestions.In the panel,15 members aged 25- 40 wereselected for sensory evaluation based on their ability to perceive and health-conscious nature. Based on the results, the best composition was finalized(Table 1), 50 g of soup mix was reconstituted in 750 ml of hot water, boiled for 2-3 minutes, and served hot for sensory evaluation. The prepared soup mix was then sealed in an aluminum laminated polythene bag for further analysis (Fig 3). The preparation and formulation of the LHOP soup mix have been depicted in Figure 2 and Table 1.

Table 1.Formulation of the LHOP soup mix

Ingredients	**g/100g**
Left over hydroid stilled orange peel flour	40
Finger millet	20
Onion	10
Tomato	10
Ginger	5
Garlic	5
Salt	4
Stevia	6
Total	100

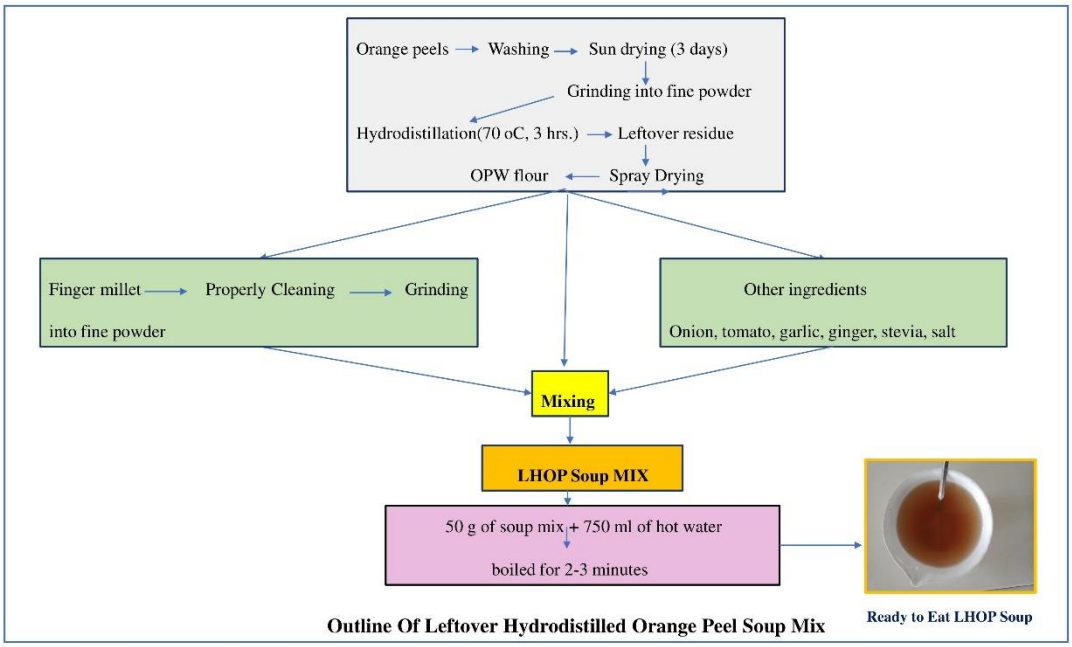

Fig 2. Outline of Leftover Hydrodistilled Orange Peel (LHOP) Soup Mix

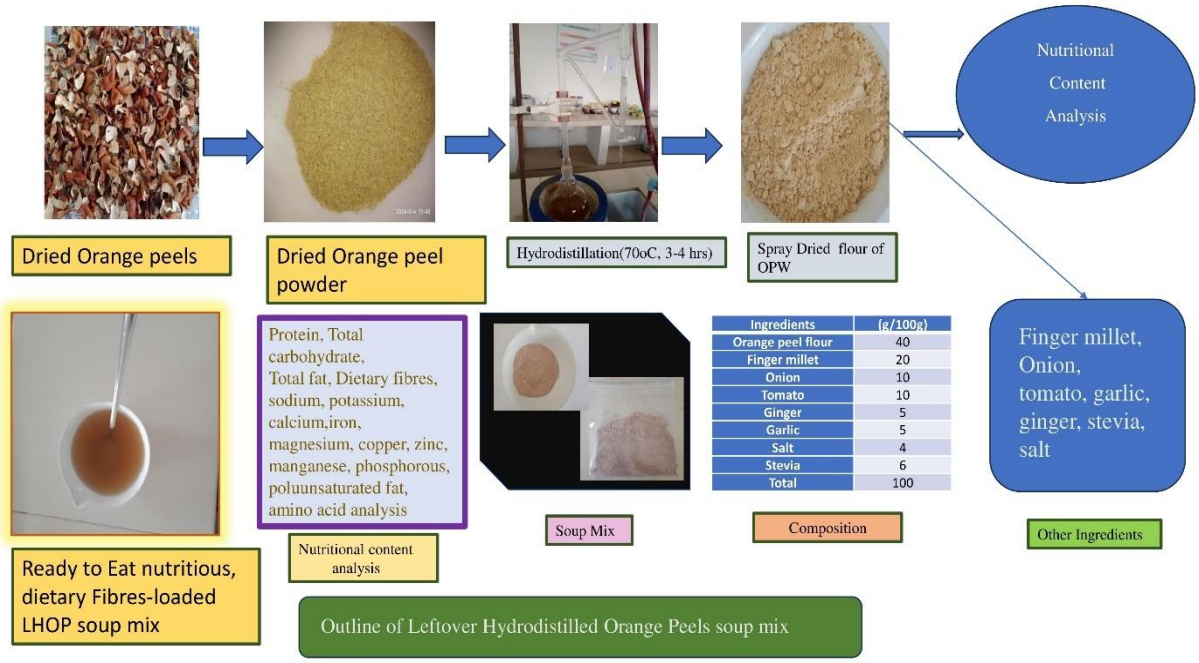

Fig 3.Formulation and evaluation of Leftover Hydrodistilled Orange Peel (LHOP) Soup Mix

Nutritional content analysis of LHOP soup mix
The standard AOAC methods as described in the nutritional content analysis of leftover hydrodistilled orange peel flour were followed for the nutritional composition of LHOP soup mix.

Mineral Profiling of LHP Soup Mix
The minerals present in LHOP soup mix were determined using an earlier reported method [10].For this, 1 g of LHOP soup mixwas added to 20 ml of diacid mixture of nitric acid and perchloric acid (9:4). The mixture was then kept overnight (undisturbed) followed by digestion at 115-118 ºC until the transparent liquid was obtained. The liquid was filtered and final volume (50 ml) was made using double distilled water. Each sample was finally subjected to atomic absorption spectroscopy to estimate the minerals.

Amino acids analysis of LHOP soup mix
Amino acids (AA) extraction from LHOP soup mix was done by mixing 0.5 g of LHOP soup mix powder in the flask with 4 ml of HCl (6 N). The sample was then maintained for 24 h in the oven at 105 ◦C to facilitate the hydrolysis of AA chains, including peptides and protein into individual amino acids. Eventually, 6 ml NaOH (6 N) was added to 2 ml of the hydrolyzed HCl sample. The resulting sample underwent centrifugation at 3500 rpm and 1 ml of supernatants were evaporated using a rotary evaporator, with 3 washes performed using distilled water to remove residual HCl. The final product was then suspended in 2 ml of distilled water and filtered through paper, then through a syringe filter, and collect in vials. A standard mix of 17 amino acids was prepared, containing alanine, glutamine, leucine, arginine, lysine, isoleucine, threonine, methionine, aspartic acid, phenylalanine, glutamic acid, tyrosine, serine, histidine, glycine, valine, and cysteine+cystine [11].

HPLC-FLD analysis
The composition of amino acids in the LHOP soup mix was studied by high-performance chromatography with fluorescence detector (EASI-CHE-HPLC-15_FLD). The chromatographic conditions were conducted with C18 column (250 × 4.6 mm; 5 µm bead size),a 43 ◦C column temperature, a fluorescence detector (λ EX = 340 nm; λ EM = 440 nm), a 1ml/min flow rate, mobile phase A (ACN –MeOH –H2O (45/45/10, v/v/v) and mobile phase B ((Na2HPO4 2,75 g/l pH = 6.4).

Sensory Evaluation of LHOP Soup Mix
The sensory quality characteristics of the*C. sinensis*LHOP soup mix, such as colour, consistency, flavour, mouthfeel, appearance and overall acceptability were assessed by 15 experienced panel members using nine-point hedonic scales developed by (Amerine et al., 1965). These are what the scores represented: This nomenclature is used: "dislike extremely", "dislike very much", “Dislike moderately”, "dislike", “neither like nor dislike", "like", "Like very much like", “like moderately”, and "extremely like", where 1 for “dislike extremely” and 9 for “extremely like” (Fig 4).

Ready to Eat LHOP Soup for Sensory Evaluation

Fig 4. Ready to eat LHOP Soup for sensory evaluation

Functional properties
The physical properties such as bulk density, tapped density, flowability, cohesiveness, swelling index and water absorption capacity were determined to confirm the LHOP soup mix physical characteristics as per the procedure method reported in an earlier investigation [12].

Bulk density
A weighed amount of LHOP soup mix powder was placed in a measuring cylinder (10 ml). The volume occupied by the soup mix in the measuring cylinder was noted and bulk density was determined using following formula.
Bulk density (g / cm^3) = Mass of powder/ Initial volume of powder

Tapped density
For tapped density, the cylinder was tapped for 5 min until no decrease in volume was observed. The final volume was recorded and tapped density was calculated using the following formula.
Tapped density (g / cm^3) = Mass of powder/ Final volume of powder

Flowability and cohesiveness (%)
The flowability and cohesiveness of LHOP soup mix was determined in terms of Carr index (CI) and Hausner ratio (HR)respectively. CI and HR were determined on the basis of tapped density and bulk density of the soup mix using following formulas.
Carr index (CI) (%) = Tapped density − Bulk density /Tapped density × 100
Hausner ratio = Tapped density /Bulk density

Swelling index (SI)
The swelling index of LHOP soup mix was determined using earlier reported method []. For this, 1.0 g of soup mix was poured into 10 ml measuring cylinder and 5 ml of distilled water was added. The volume occupied by the sample before swelling was noted. It was then allowed to stand for 1 hr without any disturbance and the volume occupied by the same sample after swelling was noted. Swelling Index was calculated using the below-mentioned formula
Swelling Index (%) = Volume occupied by sample before swelling/volume occupied by sample after swelling x 100

Water absorption capacity (WAC)
The centrifugal method was used to determine water absorption capacity. An amount of 0.1 g of soup mix powder was suspended in 10 ml of distilled water. The suspension was incubated at room temperature for 25 min followed by centrifugation at 1500 rpm for 15 min, the supernatant was collected and measured using a 10 ml measuring cylinder. The below-mentioned formula was used and water absorption capacity was calculated.
WAC (g/g) = (Initial -final solution volume)x Water density/ original weight of sample(g) x 100

Determination of heavy metals of LHOP soup mix:LHP soup mix was evaluated for the presence of heavy metals like Lead, arsenic, cadmium, and mercury by Flame Atomic Absorption Spectrometric method [13].
Shelf-life study of LHOP soup mix: The shelf life of the LHOP soup mix was periodically evaluated for one month in terms of sensory attributes after packaging it in aluminium laminated polyethylene bag. In microbial analysis total plate count, yeast and mold of the formulated soup was evaluated.

Cost of the formulated LHOP soup mix: Cost of the formulated soup mix was worked out based on input cost i.e. cost of different ingredients used for the preparation of soup, cost of packaging materials and overhead charges @10 per cent of expenditure on manufacturing which includes labour cost, depreciation cost on machinery and equipment, building etc. was included.

Statistical analysis Each analysis was carried out in triplicate. Data obtained from the phyisco- chemical and sensory analyses were subjected to analysis of variance (ANOVA). Graph-Pad prism, Version 10 (Graph pad Software, Inc.) was used for statistical analysis.

Results
Nutrient composition of LHOP flour and LHOP Soup Mix
Protein, total Carbohydrate and total fat of LHOP flour and soup mix were 6.09, 59.14, 0.12 and 11.84, 75.75 and 0.82 g/100g respectively (Table 1). Micronutrients such as sodium, potassium, calcium, iron, magnesium, copper, zinc, manganese and phosphorous were present and all were found higher in LHOP soup mix than LHOP flour. Total dietary fibre and soluble dietary fibre were 13.54 and 11.34 in LHOP flour and found higher in LHOP soup mix 22.39 and 21.63g/100g respectively. Nutrient composition was found higher in soup mix than LHOP flour may be due to additives such as finger millet and the other ingredients.

Table 2. Nutrient composition of LHOP flour and LHOP Soup Mix(g/ 100g)

Nutrients	**Composition (g/100g) Leftover Hydrodistilledorange peel flour**	**Soup mix (g/100g) (LHOP peel flour, finger millet, tomato, onion, garlic, ginger, stevia, salt)**
Protein	6.09	11.84
Total carbohydrate	59.14	75.75
Total fat	0.12	0.82
Sodium	36.18	1366.69
Potassium	1015.01	635.74
Calcium	402.14	682.37
Iron	6.5	21.68
Magnesium	8.8	98.04
Copper	0.5	3.91
Zinc	2.7	18.55
Manganese	1.8	3.71
Phosphorous	258.0	1382.81
Total Dietary Fibre	13.54	22.39
Soluble Dietary Fibre	11.34	21.63
Moisture (%)	3.76	2.57
Ash (%)	2.68	2.19

Sensory Evaluation of LHOP Soup Mix

Sensory evaluation is an effective tool to determine the quality of food products. The LHOP soup mix was evaluated for sensory tofind out the overall acceptability of the developed soup product. 15 members examined the soup mix by taste, colour and consistency etc based on a questionnaire. A nine-point hedonicscale was used and 1 is assigned for dislike extremely and nine for extremely like (Table 3). From the findings, it is evident that the formulated soup mix meets all of the examined criteria and has the potential to succeed in the market going forward.

Table 3. Sensory Evaluation of LHOP Soup Mix

Parameters	Colour and appearance	Consistency	Flavor	Mouthfeel	Overall acceptability
Observation	7.4±0.17	7.1±0.38	6.1±0.57	6.6±0.46	7.8± 0.19
Minimum score 1- dislike extremely and maximum score9- extremely like					

Values are expressed as Mean ± SD. The significance level was accepted at ($p>0.05$)

Functional Properties

Functional properties of LHOP soup mix such as bulk density, tapped density, flowability, cohesiveness, water absorption capacity and swelling index were determined (Table 4).These properties are important for manufacturers and buyers for packaging, handling, transporting and storage which are subsequently related to product quality.

Table 4. Functional Properties of LHOP Soup Mix

Sr. No	**Parameters**	**Observation**
1	Bulk Density (g/cm^3)	0.39±0.05
2	Tapped Density (g/cm^3)	0.68±0.01
3	Carr's index (%)	42.64±1.74
4	Hausner Ratio (HR)	1.74±0.07
5	Water Absorption capacity (g/100g)	2.52±0.03
6	Swelling Index (%)	5.22±1.33

Values are expressed as Mean ± SD. The significance level was accepted at ($p>0.05$)

Amino Acid Analysis of LHPSoup Mix

The HPLC-FLD analysis facilitated the identification of 17 amino acid compounds in LHOP soup mix. The most abundant amino acids were aspartic acid (760mg/100 g), proline (460mg/100g), glutamic acid (320mg/100) and alanine (310mg/100g). Furthermore, amino acids such as cysteine+cystine (20mg/100g) and methionine (10mg/100g) were among the least abundant (Table 5).

Table 5. HPLC-FLD analysis of amino acids in LHOP soup mix

Amino acid content	mg/100g
Aspartic acid	760
Serine	280
Glutamic acid	320
Glycine	140
Histidine	80
Arginine	120
Threonine	50
Alanine	310
Proline	460
Cysteine+cystine	20
Tyrosine	90
Valine	70
Methionine	10
Lysine	120
Isoleucine	90
Leucine	40
Phenylalanine	90

Heavy metal analysis of LHOP soup mix: Heavy metals are harmful and become toxic for health if they are taken above the limit of the daily allowance recommended. Its ingestion poses an increased risk to human health [14]. In this study, heavy metals were not found in our developed nutritious LHOP soup mix (Table 6).

Table 6. Heavy Metal Analysis of LHOP Soup Mix

Heavy Metals	**Result**
Lead (Pb)	ND
Arsenic (As)	ND
Cadmium (Cd)	ND
Mercury (Hg)	ND

Shelf-life Study

The developed LHOP soup mix was stored at room temperature for one month. Sensory evaluation and moisture content weredetermined on every tenth day (Table 7). Prepared LHOP soup mix was found overall acceptable in sensory evaluation right from zero-day to last 30th day. No deterioration and microbial growthwas observed during the storage period of 30 dayshowever some slight change in colour was seen but not affected the taste at all.

Table 7.Shelf-life study of LHOPSoup Mix

Parameters	**0 day**	**10th**	**20th**	**30th**
Colour (Sensory evaluation)	Light brown	Light brown	Light brown	Light brown (slight change in colour)
Moisture (%)	2.69	3.18	3.66	3.19
Microbial count	TPC- 0 Yeast and mold-0	TPC- 0 Yeast and mold-0	TPC- 1x10^3 Yeast and mold-0	TPC- 0 Yeast and mold-0

Cost of the formulated LHOP soup mix

The determination of the selling and buying price is an important thing formanufacturers and buyersas it is the primary way to compete in market competition [15]. The cost of the formulated soup mix was calculated as Rs. 35. It includesthe cost of the base ingredient, additives, packaging material and overhead charges. The calculated cost was less as base ingredient is waste material and very little machinery and manpower was used.

Conclusions

In the current studynutritional properties, functional properties and sensory characteristics of soup mix were investigated. From the results, it is evident that leftover hydrodistilled orange peel as a base ingredient and other

additives in the form of soup mix had a significant nutritional value. This soup mix is loaded with high dietary fibres and essential amino acid as well. On the other hand, sensory properties of the soup mix were found to be highly acceptable. The great benefit for the food industry mainly lies in the use of by-products from fruit peel processing, reflecting in the reduction of the environmental burden, as well as saving economic resources in production. Our study revealed that LHOP soup mix can be recognized as a suitable ingredient for food products The developed soup formulation can get applicability in the neutraceutical and food industry which can achieve consumer acceptability and preferability over other market competitors.

Acknowledgments: Authors are thankful to the President, Taywade College of Pharmacy Koradi for his valuable support. Also thankful to the Department of Science & Technology, New Delhi, India for the funding and award of the Women Scientists Scheme DST /WOSB/AFE-7/2021(G).

Author's Contribution: Priti Dongre: Writing – original draft, Investigation, Conceptualization. Chandrashekhar Doifode: Data curation, Naveen Gupta: review Dharmendra Singh Rajput- editing, Shaily Chaudhary: Supervision.

Declaration of competing Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Duda, E. (2024). Understanding Health-Related Motivations for Urban Food Self-Production in the Light of Semantic Fields Analysis. *Nutrients*, *16*(10), 1533. https://doi.org/10.3390/nu16101533
2. Barber, T. M., Kabisch, S., Pfeiffer, A. F. H., & Weickert, M. O. (2024). Dietary and Lifestyle Strategies for Obesity. *Nutrients*, *16*(16), 2714. https://doi.org/10.3390/nu16162714
3. Fernández-López, J., Botella-Martínez, C., Navarro-Rodríguez de Vera, C., Sayas-Barberá, M. E., Viuda-Martos, M., Sánchez-Zapata, E., & Pérez-Álvarez, J. A. (2020). Vegetable Soups and Creams: Raw Materials, Processing, Health Benefits, and Innovation Trends. *Plants*, *9*(12), 1769. https://doi.org/10.3390/plants9121769
4. Gajowniczek-Ałasa, D., Baranowska-Wójcik, E., &Szwajgier, D. (2024). Vegan and Vegetarian Soups Are Excellent Sources of Cholinesterase Inhibitors. *Nutrients*, *16*(13), 2025. https://doi.org/10.3390/nu16132025.
5. Grunert, K.G., Wills, J.M. (2007). A review of European research on consumer response to nutrition information on food labels. *J. Public Health* 15, 385–399.
6. https://www.statista.com/outlook/cmo/food/convenience-food/soups/india
7. Tatiane C.G., Cristina Caleja, M., Beatriz P.P., Eliana P., Lillian B. (2023). Reuse of fruits and vegetables biowaste for sustainable development of natural ingredients. *Food Bioscience*, 53,2023,102711,https://doi.org/10.1016/j.fbio.2023.102711.
8. Priti D., Shaily C., Neeraj S., Chandrashekhar D., Asiya S. (2024). Biological evaluation of leftover hydrodistilled peels of Citrus sinensis for in-vitro antioxidant and antidiabetic potential,Pharmacological Research - Modern Chinese Medicine, 11,2024,100418,https://doi.org/10.1016/j.prmcm.2024.100418.
9. Farzana T., Mohajan S., Saha T., Hossain M.N., Haque M.Z. (2017). Formulation and nutritional evaluation of a healthy vegetable soup powder supplemented with soy flour, mushroom, and moringa leaf. *Food Sci Nutr*. 3;5(4):911-920. doi: 10.1002/fsn3.476
10. Murtaza, I., Laila, O., Drabu, I., Ahmad, A., Charifi,W., Popescu, S.M., Mansoor, S. (2022). Nutritional Profiling, Phytochemical Composition and Antidiabetic Potential of Taraxacum officinale, an Underutilized Herb. *Molecules* 27, 5380. https://doi.org/10.3390/molecules27175380
11. Fatma A., Mohamed-Amine J., Ala A., Nouha D., Chayma Ben F., Samir B., Hichem S. (2024). Amino acid HPLC-FLD analysis of spirulina and its protective mechanism against the combination of obesity and colitis in wistar rats. *Heliyon.* 10: 9. https://doi.org/10.1016/j.heliyon.2024.e30103.
12. Suma H.B., Bhuvaneshwari G., Ganiger J S. Giridhar GL., Patil S.N., Chandrashekar V. M.(2023) Physical, reconstitution and phenolic properties of instant drink mix prepared with Moringa oleifera leaf, raw banana and whey protein concentrate. *Measurement: Food*. 11,2023,100108, https://doi.org/10.1016/j.meafoo.2023.100108.
13. Elgammal, S. M., Khorshed, M. A., & Ismail, E. H. (2019). Determination of heavy metal content in whey protein samples from markets in Giza, Egypt, using inductively coupled plasma optical emission spectrometry and graphite furnace atomic absorption spectrometry: A probabilistic risk assessment study. *Journal of Food Composition and Analysis, 103300.* doi:10.1016/j.jfca.2019.103300
14. Bandara S.B, Towle K.M, Monnot A.D. (2020). A human health risk assessment of heavy metal ingestion among consumers of protein powder supplements. Toxicol Rep. 21;7: 1255-1262. doi: 10.1016/j.toxrep.2020.08.001.
15. Rachman Y., halimrachmat, Radhi. (2020). Calculation Analysis of Cost of Production in Determining Product Selling Price. *Solid-State Electronics*. 63. 3896-3900.