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Protocol Refinement for the Development of Coconut Inflorescence Powder

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Coconut inflorescence holds significant potential as a nutraceutical due to its rich composition of bioactive compounds, including vitamins, minerals, and antioxidants. Its use in promoting health and preventing diseases has made it a valuable ingredient in both traditional

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medicine and modern functional foods. The aim of the study is the protocol refinement for the development of coconut inflorescence powder with acceptable moisture content and superior sensory quality.

Study Design: Completely randomized design (CRD).

Place and Duration of Study: Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Agriculture, Vellayani, Kerala Agricultural University, between May 2024 and October 2024.

Methodology: In the present study, coconut inflorescence was harvested at 5-6 months before inflorescence opening, size reduced (1 cm^3 pieces), and precooked by adopting different methods, *viz*., steaming, boiling, dry roasting, and microwave cooking (non-precooked inflorescence was used as the control). The precooked inflorescence pieces were dried by different drying methods *viz*., hot-air oven drying at 60^0C (Control), cabinet drier at 60^0C, 70^0C, 80^0C and solar drying for developing coconut inflorescence powder (CIP). CIP was analyzed for moisture content and sensory quality.

Results: CIP prepared by steaming the coconut inflorescence pieces for 30 minutes and drying in cabinet dryer at 60^0C (C1D1) recorded the least moisture content, 1.83±0.07 per cent. However, CIP prepared by boiling (95-100^0C) the inflorescence pieces by submerging for 30 minutes and drying in cabinet dryer at 60^0C (C2D1) showed the highest mean rank value for all the sensory attributes *viz*., colour (735.50), consistency (730.63), flavour (730.68), mouthfeel (734.75) and taste (735.23) on a nine-point hedonic scale with a moisture content, 4.20±0.04 per cent. The lowest mean rank value for colour was recorded by C1D1 and C2D0 (211.06). The lowest values for consistency, mouthfeel, flavour and taste were observed for the treatments C4D1 (289.81), C4D1 (290.61), C4D0 (226.05) and C0D0 (216.50), respectively. Hence, C2D1 was identified as the best precooking and drying method for the preparation of coconut inflorescence powder.

Keywords: Boiling; cabinet dryer; drying; moisture content; Precooking; sensory evaluation.

1. INTRODUCTION

The coconut tree, referred as the "Tree of Life" and "Kalpavriksha," is highly valued for its versatile benefits, including food, health, medicinal, and cosmetic uses, especially in tropical regions, earning it the title of "God's tree" in India (Ahuja et al., 2014). The coconut tree (*Cocos nucifera* L.), which belongs to the family Arecaceae, is a globally widespread fruit plant, historically used along with other natural resources for medicinal purposes (Lima et al., 2015).

Coconut inflorescence is both nutritionally and pharmacologically beneficial. An infusion of the tender coconut inflorescence could be taken orally every morning, for leucorrhoea and other menstrual cycle-related issues (Bhandary et al., 1995). Coconut inflorescence combined with rice flour, jaggery, and coconut oil was used as post-partum care, particularly for skin rejuvenation (Warrier, 1996). The flowers of *Cocos nucifera* have been identified as a rich source of phytochemicals with antidiabetic, aphrodisiac, analgesic (Khanna, 1985; Dyana and Kanchana, 2012), antimicrobial (Vadivu et al., 2020), and radical scavenging activities (Nagappan et al., 2021).

The unfermented coconut inflorescence sap was converted into a soluble white powder, rich in carbohydrates, vitamins, and minerals. Preliminary studies on mice indicated its nephroprotective properties, suggesting it may help protect epithelial cells from damage (Jose et al., 2017). Chandran (2023) had identified the right stage of harvesting coconut inflorescence for preparing dietary supplements, standardized anti browning treatment (one per cent sodium chloride and citric acid for five minutes) and drying (hot-air oven at 60^oC) protocols for the development of CIP. The scholar also developed a novel coconut inflorescence dietary supplement (CIDS) with enhanced pharmacological properties and nutritional benefits, aiming at suspects having type 2 diabetes. However, the standardized protocol for the development of CIDS is inadequate for completely cooking the starch in the inflorescence, necessitating additional cooking before consumption and leaving room for improving its physical and sensory quality.

2. MATERIALS AND METHODS

In the present study, the coconut inflorescence was collected from healthy palms (older than 20

years) of the WCT variety, five to six months before the inflorescence opening or three to four months after the inflorescence emergence. The inflorescence powder was be produced by size reducing (1 cm^3 pieces) it using a sharp stainless-steel knife, followed by soaking in a solution containing one per cent sodium chloride and citric acid for five minutes (Chandran and Sonia, 2022). Inflorescence pieces were precooked by adopting different methods *viz*., C0: Fresh coconut inflorescence (Control), C1: Steaming for 30 minutes, C2: Boiling (95-100^{0}C) by submerging for 30 min, C3: Dry roasting in a hot plate in medium flame for 25 min and C4: Microwave cooking in microwave oven (NN-ST266B FDG and Panasonic) in medium (700 Watts) power for 8-10 minutes (100g). Pre-cooked inflorescence pieces were subjected to air drying at ambient room temperature conditions to drain the excess water content using the following drying methods. The pre-cooked inflorescence pieces were spread evenly in drying trays and placed inside the hot air oven (BHO-05UD, Beston) at 60^{0}C (control), cabinet drier (KCTD-ISP, KEMI (kadavil electro-mechanical industries) at 60^{0}C, 70^{0}C, and 80^{0}C and also solar drier. The pre-cooked and dried coconut inflorescence samples were ground into powder using a mixer grinder, sieved (180 µm) to produce coconut inflorescence powder (CIP), and packaged in airtight containers. A superior pre-cooking and drying method will be identified by analyzing moisture content and the sensory quality of the samples.

2.1 Moisture Content

The moisture content of one-gram sample of precooked and dried coconut inflorescence was measured using a moisture analyzer (MA 150, Sartorius). This instrument utilizes a halogen lamp for drying, and the moisture content subsequently determined as percentage based on the principles of thermogravimetric analysis (Sonia, 2012).

2.2 Sensory Quality

Sensory quality of the coconut inflorescence powder (CIP) was assessed by judging the sensory attributes *viz*., colour, consistency, flavour, mouthfeel and taste of CIP porridge sweetened using palm jaggery (10g) by following Chandran (2023). The porridge was prepared by mixing CIP (20g) with water (300ml) followed by cooking for approximately 10 minutes.

Sensory evaluation of the prepared porridge was performed by a 30-member panel consisting of semi-trained individuals, including research scholars and faculty members from the College of Agriculture, Vellayani. A specifically designed scorecard was employed for the purpose of conducting sensory analysis, and the hierarchy of preferences is outlined as follows.

Excellent : 9-10
Good : 7-8
Fair : 5-6
Poor : 3-4
Bad : 1-2

3. RESULTS

For the development of coconut inflorescence powder, coconut inflorescence harvested at 5-6 months before inflorescence opening (i.e., three to four months after inflorescence emergence) was taken, the inflorescence was size reduced (1 cm^3 pieces) and treated with anti-browning agents (Chandran and Sonia, 2022). Inflorescence pieces were precooked by adopting different methods *viz.,* C0: fresh coconut inflorescence (control), C1: steaming for 30 minutes, C2: boiling (95-100^{0}c) by submerging for 30 minutes, C3: dry roasting and C4: microwave cooking. The precooked inflorescence pieces were dried by different drying methods *viz.,* D0: hot-air oven drying at 60^{0}C (control), D1: cabinet drier at 60^{0}C, D2: cabinet drier at 70^{0}C, D3: cabinet drier at 80^{0}C and D4: solar drying. The coconut inflorescence powder was analyzed for moisture content and sensory parameters.

3.1 Moisture Content

The moisture content of CIP was analyzed and the findings are presented in Table 1. Among the precooking method samples that were dry roasted (C3 – dry roasting) recorded the minimum moisture content, 3.02±0.93 per cent. The maximum moisture content was recorded in the uncooked coconut inflorescence samples (C0- fresh coconut inflorescence sample (control)), 7.14±2.16 per cent. Among the drying methods, coconut inflorescence pieces dried in cabinet drier at 80^{0}C (D3) had the lowest moisture content, 3.22±1.07 per cent. On the other hand, the treatment D0 [Hot-air oven drying at 60^{0}C (Control)] exhibited the highest moisture content, 5.60±1.53 per cent. The interaction between precooking and drying methods (C×D) considerably influenced the moisture content of the final product. C1D1

(Steaming for 30 minutes and drying in cabinet drier at 60^{0}C) recorded the least moisture content, 1.83±0.07 per cent, which was on par with C3D2 (2.22±0.11 per cent), C4D2 (1.96±0.07 per cent) and C4D3 (2.04±0.14 per cent).

Table 1. Moisture content of coconut inflorescence powder

Treatments	Moisture (%)
Precooking methods (C)	
Fresh coconut inflorescence (Control) (C0)	7.14±2.16^{a}
Steaming for 30 minutes (C1)	3.33±0.93^{c}
Boiling (95-100^{0}C) by submerging for 30 minutes (C2)	5.07±0.79^{b}
Dry roasting (C3)	3.02±0.93^{cd}
Microwave cooking (C4)	3.07±1.15^{cd}
CD	0.19
CV	4.75
SE(m)	0.06
Drying methods(D)	
Hot-air oven drying at 60^{0}C (Control) (D0)	5.60±1.53^{a}
Cabinet drier at 60^{0}C (D1)	4.20±2.79^{c}
Cabinet drier at 70^{0}C (D2)	4.26±2.41^{c}
Cabinet drier at 80^{0}C (D3)	3.22±1.07^{d}
Solar drying (D4)	4.53±1.29^{b}
CD	0.19
CV	4.75
SE(m)	0.06
Interaction (C×D)	
C0D0	7.99±0.37^{b}
C0D1	9.28±0.36^{a}
C0D2	8.30±0.14^{b}
C0D3	3.38±0.12^{g}
C0D4	6.76±0.32^{c}
C1D0	3.92±0.18^{ef}
C1D1	1.83±0.07^{i}
C1D2	4.05±0.12^{e}
C1D3	2.81±0.09^{h}
C1D4	4.04±0.07^{e}
C2D0	6.41±0.45^{c}
C2D1	4.20±0.04^{e}
C2D2	4.80±0.21^{d}
C2D3	5.06±0.18^{d}
C2D4	4.88±0.13^{d}
C3D0	4.78±0.18^{d}
C3D1	2.79±0.31^{h}
C3D2	2.22±0.11^{i}
C3D3	2.82±0.12^{h}
C3D4	3.42±0.12^{g}
C4D0	4.90±0.16^{d}
C4D1	2.92±0.15^{h}
C4D2	1.96±0.07^{i}
C4D3	2.04±0.14^{i}
C4D4	3.56±0.15f^{g}
CD	0.42
CV	4.75
SE(m)	0.14

Table 2. Sensory quality of coconut inflorescence powder prepared by precooking and drying

Treatments	Mean rank value				
	Colour	Consistency	Flavour	Mouth Feel	Taste
C0D1	212.18^{a}	441.58^{ab}	426.03^{ab}	348.43^{abcdef}	316.28^{abcd}
C0D2	473.03^{b}	422.86^{abc}	423.38^{abc}	379.26^{abcdg}	344.05^{abcef}
C0D3	629.50^{cd}	472.16^{a}	472.46^{a}	490.00^{hi}	456.95^{ghi}
C0D4	217.18^{a}	361.00^{bcde}	361.70^{bcde}	303.93^{adefjk}	306.41^{abcd}
C1D0	223.30^{a}	395.23^{abcde}	395.83^{abcde}	270.90^{efjk}	383.18^{abefgh}
C1D1	211.06^{a}	307.56^{de}	308.46^{de}	329.00^{acdefjk}	281.58^{acd}
C1D2	457.23^{b}	340.63^{bcde}	341.36^{bcde}	450.13^{bghi}	356.48^{abcefg}
C1D3	248.10^{ae}	408.88^{abcd}	409.38^{abcd}	326.78^{acdefjk}	309.30^{abcd}
C1D4	217.18^{a}	341.00^{bcde}	341.65^{bcde}	336.16^{acdefj}	432.81^{eghi}
C2D0	211.06^{a}	306.68^{de}	307.51^{de}	275.31^{aefjk}	462.98^{hi}
C2D1	735.50^{c}	730.63^{f}	730.68^{f}	734.75^{l}	735.23^{j}
C2D2	438.71^{bf}	348.36^{bcde}	349.00^{bcde}	415.66^{bcgh}	387.10^{abefgh}
C2D3	615.06^{d}	338.81^{bcde}	339.65^{bcde}	554.11^{i}	526.06^{i}
C2D4	237.76^{ae}	344.76^{bcde}	354.50^{bcde}	384.48^{bcdgh}	349.18^{abcef}
C3D0	212.18^{a}	393.93^{abcde}	394.50^{abcde}	256.95^{ejk}	367.15^{abcefgh}
C3D1	283.93^{ae}	366.78^{abcde}	367.36^{abcde}	316.56^{acdefjk}	320.90^{abcdf}
C3D2	468.26^{b}	332.08^{cde}	332.81^{bcde}	377.16^{abcdfg}	422.91^{efghi}
C3D3	591.35d^{g}	317.05^{cde}	317.86^{cde}	477.50^{ghi}	385.80^{abefgh}
C3D4	225.21^{a}	350.51^{bcde}	351.23^{bcde}	342.00^{acdefj}	350.16^{abcef}
C4D0	308.96^{ae}	353.75^{bcde}	354.45^{bcde}	226.05^{k}	345.78^{abcef}
C4D1	269.83^{a}	289.81^{e}	290.61^{e}	312.15^{acdefjk}	299.76^{acd}
C4D2	522.51^{bg}	347.48^{bcde}	348.30^{bcde}	411.45^{bcgh}	410.81^{befgh}
C4D3	647.73^{cd}	352.28^{bcde}	352.95^{bcde}	481.45^{ghi}	352.23^{abcefg}
C4D4	338.56^{ae}	360.91^{bcde}	361.51^{bcde}	348.43^{abcdef}	267.83^{cd}
C0D0	391.96^{ef}	362.68^{bcde}	363.25^{bcde}	238.83^{jk}	216.50^{d}
K value	456.64	116.34	114.61	201.77	165.94
p value	0	0	0	0	0

3.2 Sensory Quality

CIP porridge prepared by various precooking methods followed by different drying methods was evaluated for sensory attributes, *viz*., colour, consistency, flavour, mouth feel and taste (Table 2). Porridge of CIP samples prepared by boiling (95-100^{0}C) and submerging for 30 minutes and followed by drying in cabinet dryer at 60^{0}C (C2D1) recorded highest mean rank value, 735.50 for colour. The lowest mean rank value for colour was recorded by C1D1 and C2D0, 211,06. The lowest values were on par with C0D1, C0D4, C1D4, C3D0, C3D4 and C4D1. Consistency of porridge prepared using CIP by C2D1 (boiling (95-100^{0}C) by submerging for 30 minutes and drying in cabinet dryer at 60^{0}C) recorded the highest mean rank value, 730.63. The lowest mean rank value for consistency was recorded for CIP prepared by microwave cooking followed by drying in cabinet drier at 60^{0}C (C4D1), 289.81. Flavour of the CIP porridge was found to be significantly higher (730.68) in C2D1 boiling (95-100^{0}C) by submerging for 30 minutes and drying in cabinet dryer at 60^{0}C. The lowest mean rank value was recorded for C4D1 (Microwave cooking and drying in cabinet drier at 60^{0}C), 290.61. CIP porridge prepared using the powder obtained by boiling (95-100^{0}C) and submerging for 30 minutes and subsequently drying in cabinet dryer at 60^{0}C (C2D1) showed the highest mean rank value for mouthfeel, 734.75. The lowest mean rank value for mouth feel was recorded for C4D0, 226.05. Taste of the CIP porridge was highest for C2D1 (boiling (95-100^{0}C) by submerging for 30 minutes and drying in cabinet dryer at 60^{0}C) with a mean rank value, 735.23. The lowest mean rank for taste was recorded for C0D0 (fresh coconut inflorescence sample dried by hot-air oven drying at 60^{0}C, 216.50.

The CIP prepared by steaming the coconut inflorescence pieces for 30 min and drying in cabinet dryer at 60^{0}C (C1D1) recorded the least moisture content, 1.83±0.07 %. However, CIP prepared by boiling (95-100^{0}C) the inflorescence pieces by submerging for 30 minutes and drying in cabinet dryer at 60^{0}C (C2D1) shows the highest mean rank value for all the sensory

attributes *viz*., colour (735.50), consistency (730.63), flavour (730.68), mouthfeel (734.75) and taste (735.23) with a moisture content, 4.20±0.04 per cent. Hence, C2D1 was identified as the best precooking and drying method for the preparation of CIP.

4. DISCUSSION

4.1 Moisture Content

Fig. 1. evidently demonstrates that among the precooking and drying methods adopted for the development of CIP, fresh coconut inflorescence pieces (C0) dried in hot air oven at 60^0C (D0) exhibited the highest moisture content, 9.28±0.36 %.

However, the inflorescence pieces steamed (C1) for 30 minutes and dried in cabinet drier at 60^0C recorded the least moisture content, 1.83±0.07 per cent. The reduced moisture content in the dried samples followed by steaming might be attributed to protein denaturation and the resultant failure of capillary forces to hold water within the protein structures (Aaslyng et al., 2003). A related experience was observed in dried cashew kernels (70°C) (Kosoko et al., 2009) and dried white shrimp (*Litopenaeus vannamei*) (Rostini and Pratama, 2018) pre-treated by steaming 40 minutes and 30 minutes respectively.

When comparing the non-precooked coconut inflorescence pieces with precooking by boiling, irrespective of the drying methods adopted, CIP prepared using boiled inflorescence pieces recorded minimum moisture content. Boiling as a pre-treatment before drying benefiting less moisture content in *Mactra veneriformis* was explained by Wang et al. (2023). Synonymous to steaming, pre-treatment during boiling also cause protein denaturation that could diminish water holding capacity of boiled samples (Costa et al., 2018). Wang et al. (2023) could observe an enhanced water mobility and reduced moisture content in the boiled samples during the final phase of hot air drying using Page model combined with LF-NMR and MRI techniques.

Meanwhile when the dried inflorescence pre-treated by steaming (C1) and boiling (C2) when compared, steamed samples recorded lower moisture content. Severo et al. (2013) proved that thermal treatment of *Eucalyptus dunnii* using steam (100ºC for 3 hours) could reduce the initial moisture content by 9.2% and an increased drying rate by 6.2%. Nevertheless, the moisture content of CIP produced through each drying method after following dry roasting (C3) or microwave cooking (C4) is approximately equal. During dry roasting and microwave cooking the internal heat in the produce creates a water vapour pressure within it which creates a pressure gradient between the surface and interior resulting in rapid water removal (Perez et al., 2019; Haneef et al., 2023).

4.2 Sensory Quality

When a sensory evaluation was carried out on coconut inflorescence powder porridge, prepared using various precooking and drying methods, assessing parameters such as colour, consistency, flavour, mouthfeel, and taste. Fig. 2. clearly shows that the porridge prepared using the coconut inflorescence powder sample prepared by submerging the inflorescence pieces in boiling water (95-100°C) for 30 minutes and dried in cabinet dryer at 60°C (C2D1) achieved the highest mean rank for colour (735.50), consistency (730.63), flavour (730.68), mouthfeel (734.75) and taste (735.23). However, the control sample prepared using the coconut inflorescence pieces dried in hot air oven at 60°C (D0) without any precooking (C0) reported the lowest mean rank value for taste (216.5) and mouthfeel (238.83). Meanwhile, the control has recorded poor values for colour (391.96), consistency (362.68) and flavour (363.25) too. It is apparently clear from the Plate 1. that pre-cooking and drying followed in the current research could produce apparent improvement in sensory quality parameters especially colour compared to the control.

Chandran and Sonia (2022) could produce coconut inflorescence powder having superior sensory quality by soaking the chopped inflorescence in anti-browning agent combination: citric acid (1%) + sodium chloride (1%) for five minutes followed by drying in hot-air oven at 60°C. Mean rank values for the sensory attributes *viz*., colour, consistency, flavour, mouth feel, and taste were 546.23, 527.35, 526.28, 541.35 and 525.15, respectively. However, the best treatment in the present experiment (C2D1) recorded more acceptance than the control samples prepared by following Chandran and Sonia (2022).

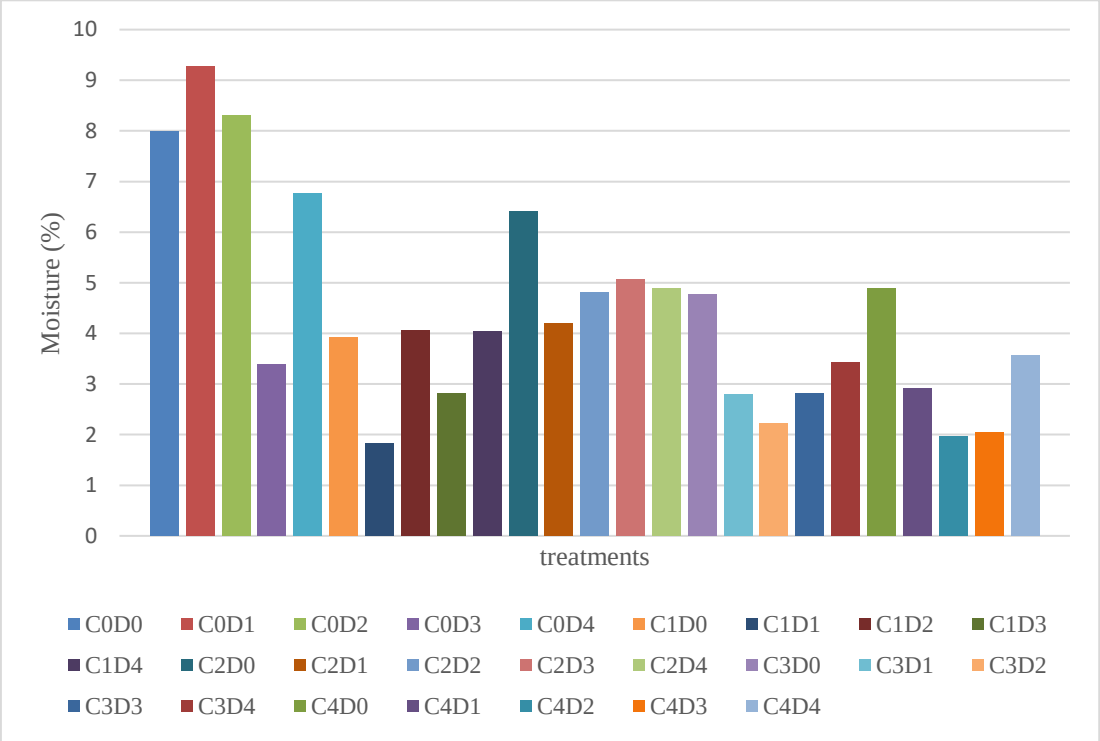

Fig. 1. Moisture content of coconut inflorescence powder

Control (C0D0) C2D1

Plate 1. Colour enhancement of Coconut inflorescence powder

Control v/s CIP prepared by boiling in water (95-100°C) for 30 minutes and drying in cabinet dryer at 60°C (C2D1)

The influence of boiling in colour improvement of agricultural produces were explained by different scholars. Shamaruddin et al. (2021) developed boiled black jelly mushroom (*Auricularia polytricha*) processed product having significantly high L* (lightness) value (38.96) and taste (7.34) compared to stir-fried (29.93) and fresh uncooked mushrooms (34.62). Wang et al. (2023) developed light-coloured *Mactra veneriformis* dried product after boiling. The possible reasons for impairment in colour during heat treatments are pointed out in various raw materials. The fruiting bodies of *Agaricus bisporus* darken during heat treatment due to nonenzymatic oxidative alterations in the polyphenol compounds (Zivanovic et al., 2003). Heat treatment enhances the hydrolysis of proteins and starches, leading to the formation of compounds capable of participating in carbonyl-amine reactions, which contribute to the discolouration of the product. The colour changes observed during stir-frying are primarily due to the maillard reaction, which results in a darkening of the food and a shift in surface colour towards brown tone (Hofman, 1998; Serpen and Gokmen, 2009).

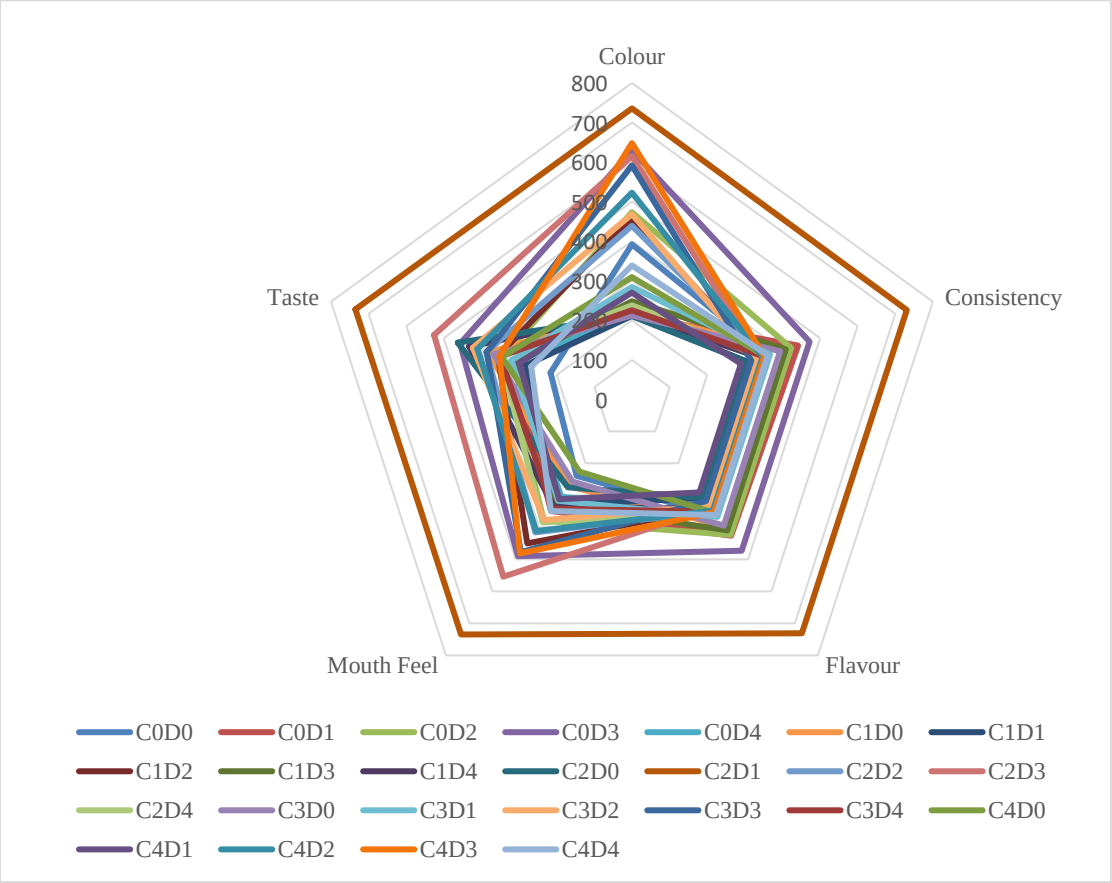

Fig. 2. Sensory quality of Coconut Inflorescence Powder

Therefore, pre-cooking [boiling water (95-100°C) for 30 minutes] and drying (cabinet dryer at 60°C) could be considered as the best set of pre-treatments to be followed in coconut inflorescence pieces along with soaking in anti-browning agent (citric acid (1%) + sodium chloride (1%) for five minutes) for improving the moisture content and all the sensory quality parameters of the coconut inflorescence powder.

5. CONCLUSION

Coconut inflorescence, rich in bioactive compounds, has considerable potential as a nutraceutical, contributing to both health promotion and disease prevention. The development of high-quality coconut inflorescence powder (CIP) involved assessing various precooking and drying techniques. Superior quality coconut inflorescence powder could be produced using inflorescence harvested at 5-6 months before inflorescence opening, size reduced ($1cm^3$), treated with antibrowning agents followed by boiling it for 30 minutes and drying in cabinet dryer at 60°C. The developed product exhibited superior sensory characteristics *viz*., colour (735.50), consistency (730.63), flavour (730.68), mouthfeel (734.75) and taste (735.23), while maintaining an acceptable moisture level (4.20±0.04 per cent. With optimized processing, coconut inflorescence could be further developed into a premium functional food product. Future research could focus on nutrient bioavailability, specific health benefits, and its potential application of CIP in food fortification and product innovation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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