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Effect of different pretreatments and drying methods on physico-chemical properties of mahua flowers

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Abstract
This study was conducted to investigate the effect of different pretreatments and drying methods on the physico-chemical properties of mahua flower (*Madhuca longifolia*). In the present study, two pretreatments i.e. potassium metabisulphite (KMS), citric acid and one control sample, were combined with three drying methods i.e. sun drying, shade drying and tray drying. The dried mahua flowers obtained from different treatment combinations were evaluated for colour and physico-chemical properties. Among the pretreatments, KMS treatment showed superior performance for colour L* (21.10), a* (21.08) and b* (13.71), moisture (17.60%), alcohol soluble extractive (26.41%), water soluble extractive (71.86%), total ash (3.92%), acid insoluble ash (2.31%), total tannin content (906.26 mg/100g), total phenol content (3576.87 mg/100g), total flavonoid content (1975.86 mg/100 g), TSS (79.34°Brix), total sugar (58.09%), reducing sugar (45.12%) and acidity (0.450%). Among the drying methods, tray drying showed superior performance for colour L* (23.67), a* (13.89) and b* (16.01), moisture (17.27%), alcohol soluble extractive (27.35%), water soluble extractive (73.59%), total ash (4.86%), acid insoluble ash (2.58%), total tannin (1078.61mg/100 g), total phenol content (3647.50 mg/100 g), total flavonoid content (2108.77mg/100 g), TSS (79.16°Brix), total sugar (61.31%), reducing sugar (46.30%) and acidity (0.461%). The combination of KMS pretreatment and tray drying was found to be the most effective treatment for obtaining good-quality dried mahua flowers.

Keywords: Mahua flowers (*Madhuca longifolia*), pre-treatments, KMS, drying methods, tray drying and physico-chemical properties

1. Introduction

Madhuca longifolia (Mahua) belongs to family Sapotaceae, is a saponaceous tree with a high economic value, providing the two most important non-timber forest products are mahua flower and mahua seed. It is a multipurpose forest tree species that provides solutions for the three key factors are food, fodder and fuel. *Madhuca*, also known as Mahua or Mowarh in the north, Mahula in Odisha and Illipi in the south, is also known in Sanskrit as Madhuka, Madhudruma, Madhupuspa, Madhusakha and Gudapuspa. In marathi it is commonly known as Moha. The name is derived from the Sanskrit word madhu (meaning honey), which refers to the blooms' high sugar content. It is native to the Indian subcontinent and abundantly spread in the dry deciduous woods of central India. Mahua flowers are one of the most important non-timber forest products collected in the country (Patel and Naik, 2008) [14].

Mahua tree is deciduous tree, with 12-15m height and flowers are white or yellowish-white numerous fleshy crowded from outermost of branches. Fruits are fleshy, ovoid locally called as Tori. Plants are leafless during February - April. Different parts of tree are being used since ages in medicines and other uses (Jakhi and Kalkar, 2011) [7].

Flowers are used as diuretics, tonics and analgesics. Flowers have long been used as a cooling agent, tonic, aphrodisiac, astringent and demulcent. They are also used to treat bronchitis, pharyngitis, acute and chronic tonsillitis and helminths. Additional uses include anthelmintic, demulcent, laxative, stimulant and tonic; fomentation with dried ones relieves orchids; decoction is used as an expectorant; when taken with milk, it helps with impotence caused by general debility (Chandra, 2001) [3].

Drying is the process of removing water from a food item to a certain amount in order to increase shelf life and reduce water activity in the commodity. It contributes significantly to the product's preservation (Doymaz, 2004) [5]. Drying a small quantity of medicinal herbs without the use of additional sources of energy is one of the most popular methods. Medicinal plants should be dried as soon as possible after harvesting in order to improve a plant quality and reduce losses due to contamination (Irondi *et al*. 2013) [6].

2. Materials and Methods

2.1.1 Plant material

The Mahua flowers were collected from local farmers from Saralgaon village and surrounding area Murbad tahsil of Thane district Maharashtra.

2.1.2 Place, duration and season of the experiment place

Department of Post-Harvest Management of Medicinal, Aromatic, Plantation, Spice and Forest Crops (MAPSF), Post Graduate Institute of Post-Harvest Management Killa-Roha, District Raigad during 2025-26.

2.1.3 Experimental Site

The experiment was conducted at Post Graduate Institute of Post-Harvest Management Killa-Roha, under Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M. S.).

2.1.4 Flowchart of experiment

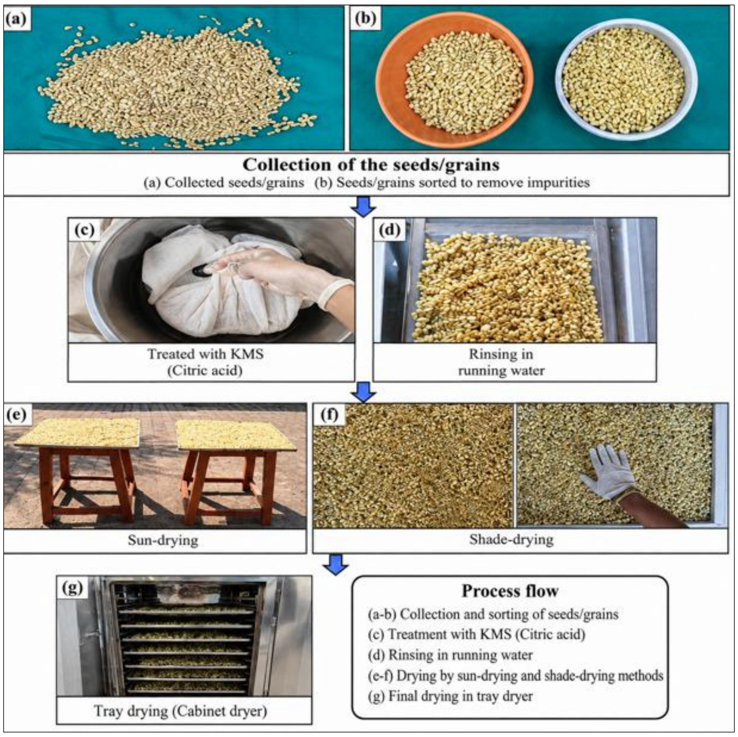

Fig 1: Process flow for the collection, pretreatment, and drying of mahua flowers using different drying methods

2.1.5 Effect of various pretreatment and drying method on mahua flower

Fig 2: Appearance of mahua flowers dried using different pretreatments and drying methods

2.2 Physical parameters of mahua flowers

2.2.1. Colour (L*, a* and b* value)

The colorimeter (Model CR 400/410 chromameter, Konica Minolta Holdings Inc., Tokyo,. Japan) was used to measure the colour of the mahua flower. The results were reported using the Hutchings CIE lab system, taking into account illuminant D65 and a viewing angle of 10 degrees Celsius. The colour of the mahua flower was measured using the L*, a*and b* values (Nard *et al*.1996) [13].

2.2.2 Moisture content (%)

The moisture content in the sample was determined by using the moisture analyser. The moisture content of the given sample was determined by using the following formula (Ranganna, 1986) [17].

Moisture content (%) = $\frac{Ww - Wd}{Wd} \times 100$

Where,
Ww= initial weight of sample (g)
Wd = weight of dry sample (g)

2.3 Chemical parameters

2.3.1 Alcohol soluble extractive value (%)

5g coarsely powdered air-dried rug was macerated with 100 ml of alcohol of the specified strength in a closed flask for 24hrs. It was then continuously shaken for 6hrs using rotary shaker and allowed to stand for 18hrs. The content was filtered using filter paper. The filtrate was transferred to a pre-weighed flat-bottomed dish was kept in oven at 105◦, to constant weight and weigh. The percentage of alcohol-soluble extractive was calculated with reference to the air-dried drug.

Alcohol soluble extractive Value (%) =

$$\frac{\text{Weight of residue (g)}}{\text{Weight of sample (g)}} \times 100$$

(Lohar, 2007) [10]

2.3.2 Water soluble extractive Value (%)

Procedure was same as that of alcohol soluble extractive value and it was proceeded using distilled water instead of alcohol.

Water soluble extractive Value (%) =

$$\frac{\text{Weight of residue (g)}}{\text{Weight of sample (g)}} \times 100$$

(Lohar, 2007) [10]

2.3.3 Total ash (%)

Silica Crucible was cleaned, dried well, labelled with glass pencils and then weighed to constant weight. 5 gm of powdered drug sample was put in the Silica crucible. The drug was spread evenly in to a thin layer. This crucible was placed in a muffle furnace and ignited at a temperature of 600°C for about 6 hrs or more until the ash was totally free from Carbon. The crucible containing the ash was allowed to be cooled in desiccators and subsequently weighed to constant weight. The percentage of ash with reference to the air-dried drug was calculated.

Total ash (%) =

$$\frac{\text{Weight of crucible with ash} - \text{Weight of the crucible}}{\text{Weight of sample (g)}} \times 100$$

(Lohar, 2007) [10]

2.3.4 Acid insoluble ash (%)

Acid insoluble Ash value determined as per Pharmacopoeia of India, 1996. Boiled the total ash with 25 ml of 2M hydrochloric acid for 5 minutes, collected the insoluble matter in a Gooch crucible or on an ashless filter paper, washed with hot water, ignite, cool in a desiccator and weighed. Calculate the percentage of acid - insoluble ash with reference to the air -dried drug.

Acid insoluble ash =

$$\frac{\text{Weight of crucible} + \text{ash} - \text{Weight of the crucible}}{\text{Sample dry weight}} \times 100$$

(Lohar, 2007) [10]

2.3.5 Total tannin content (mg /100 gm)

Stock solution of 1 mg/ml of tannic acid was prepared by dissolving 100 mg of accurately weighed tannic acid in water. About 1-10 ml aliquots were taken in clear test tube and 0.5 ml of Folin-Denis reagent, 1 ml of sodium carbonate solution were added to each test tube. Each tube was made upto 10 ml with distilled water. All the reagents in each tube were mixed well and kept undisturbed for about 30 min and read at 760 nm against blank reagent.

Total Tannin content (mg /100 gm) = $\frac{Ce \times V}{W} \times 100$

Were,
CE = Catechin equivalents (mg/mL),
V = Volume of test sample (mL),
W = Sample (Velavan, 2015) [21]

2.3.6 Determination of total flavonoid content (mg /100 gm)

Aluminium chloride method

Aqueous extract was mixed with 0.1 ml of 10% aluminium chloride, 0.1 ml of 1 M potassium acetate and 2.8 ml of deionized water. After the 40 minutes of incubation at the room temperature, the absorbance for the mixture was determined spectrophotometrically at 415 nm. Quercetin was chosen as a standard and the total flavonoid content was expressed as milligram quercetin equivalents per g of dry extracts.

Total Flavonoid content (mg /100 gm) = $\frac{QE \times V}{W} \times 100$

Where, QE = the conc. of quercetin established from the calibration curve, mg/mL, V W = Volume of test sample (mL),
W= weight of sample extract (distillate) (g) (Velavan, 2015) [21]

2.3.7 Total Soluble Solids (° Brix)

The total soluble solids were determined by using Hand Refractometer (Atago Japan,) and the values were corrected at 20 °C with the help of temperature correction chart (A.O.A.C., 2020).

2.3.8 Total sugar (%)

For inversion at room temperature, a 50 ml aliquot of clarified deleaded solution was transferred to 250 ml volumetric flask, to which, 10 ml of 50 per cent HCl was added and then allowed to stand at room temperature for 24 hrs. It was then neutralized with 40 per cent NaOH solution. The volume of neutralized aliquot was made to 250 ml with distilled water. This aliquot was used for determination of total sugars by titrating it against the boiling mixture of Fehling 'A' and Fehling 'B' (5ml each) using methylene blue as indicator to a brick red end point. There results were expressed on per cent basis.

Total Sugar (%) = $\frac{\text{Factor} \times \text{Dilution} \times 5}{\text{Titrate reading} \times \text{Weight of sample}} \times 100$

(Ranganna, 1986) [17]

2.3.9 Reducing sugar (%)

The reducing sugars were determined by the method of Lane and Eynon (1923) [9] as described by Ranganna (1986) [17]. A known weight of sample was taken in 250 ml volumetric flask. To this, 100 ml of distilled water was added and the contents were neutralized by 1 N sodium hydroxide. Then, 2 ml of 45 per cent lead acetate was added to it. The contents were mixed well and kept for 10 minutes. Two ml of 22 per cent potassium oxalate was added to it to precipitate the excess of lead. The volume was made to 250 ml with distilled water and solution was filtered through Whatman No. 4 filter paper. This filtrate was used for determination of reducing sugars by titrating it against the boiling mixture of Fehling 'A' and Fehling 'B' solutions (5 ml each) using methylene blue as indicator to a brick red end point.

The results were expressed on per cent basis.

Reducing Sugars (%) = $\frac{\text{Factor} \times \text{Dilution}}{\text{Titrate reading} \times \text{Weight of sample}} \times 100$

(Ranganna, 1986) [17]

2.3.10 Acidity (%)

A known quantity of sample was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator (A.O.A.C. 2020). The sample of known quantity with 20 ml distilled water was transferred to 100 ml volumetric flask, made up the volume and filtered. A known volume of aliquot (10 ml) was titrated against 0.1N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator (Rangana, 1986). The results were expressed as per cent anhydrous citric acid.

Acidity (%)

$$= \frac{\text{Normality of alkali} \times \text{Titrate reading} \times \text{Volume made} \times \text{Equivalent weight of acid}}{\text{Weight of sample taken} \times \text{Volume of Sample taken for estimation} \times 1000} \times 100$$

(Ranganna, 1986) [17]

3. Result and Discussion

3.1 Physical parameters of mahua flower

3.1.1 Colour (L*, a* and b*)

The colour of flower was estimated by colorimeter which gives the L*, a* and b* values which stands for perceptual lightness, red and green, yellow and blue, respectively.

L* value

The data for L* value for colour of Mahua flower are presented in Table (1). The L* value represents the lightness of dried mahua flowers. A higher L* value indicates a lighter colour, while a lower value indicates greater browning P_1 (KMS) showed the significantly highest mean L* value (21.10) of all the pre-treatments, followed by P_2 (Citric acid) (19.07) and P_3 (Control) (14.16). The pre-treatment differences were greater than the critical difference at 5%.

Among the different drying methods, the significantly highest (23.67) mean L* value were recorded in drying method T_3 (Tray drying) followed by all drying methods, followed by T_1 (Sun drying) (19.75) and T_2 (Shade drying) (10.90) respectively. It was found that there is a statistically significant interaction between drying method and pretreatment. KMS pretreatment and tray drying ($P_1 \times T_3$) shows the maximum (27.69) L* value where control and shade drying ($P_3 \times T_2$) had the lowest value (9.40).

The colour parameter (L*) is given in Table no. 1 in which L* value ranges from 9.40 to 27.69 respectively and were significantly affected ($p \leq 0.05$) by both blanching duration and potassium metabisulphite (KMS) concentration. The optimized treatment resulted in higher colour values (L = 27.76) compared to the control, suggesting superior colour retention. The researchers note that extending blanching time from 0 to 3 minutes improved L* values, likely due to deactivating enzymes that cause browning. However, longer blanching periods reduced colour quality, as excessive heat led to pigment degradation. Moreover, higher KMS concentrations enhanced colour preservation by preventing browning reactions. KMS suppressed polyphenol oxidase activity, thereby limiting enzymatic browning and also interfered with non-enzymatic browning via the Maillard reaction. Consequently, the combined use of optimal blanching and KMS treatment effectively reduced both types of browning in dried mahua flowers. The result is noted by Pinakin *et al*. (2020) [15].

Table 1: Effect of different pretreatments and drying methods on L* colour value of mahua flower

Pre-Treatment	Colour L* value			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	23.87	11.75	27.69	21.10
P_2: Citric Acid	20.12	11.55	25.52	19.07
P_3: Control	15.26	9.40	17.81	14.16
Mean	19.75	10.90	23.67	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.12		0.38	
Drying Methods (T)	0.12		0.38	
Interaction (P × T)	0.22		0.66	

a* value

The data for a* value for colour of Mahua flower are presented in Table 2. Among the various pre-treatments the significantly highest (25.90) mean a* value was recorded in P_3 (Control), followed by P_2 (Citric acid) (21.77) and P_1 (KMS) (21.08) respectively.

Among the different drying methods, the significantly highest (29.97) mean a* value recorded in T_2 (Shade drying), followed by T_1 (Sun drying) (24.88) and T_3 (Tray drying) (13.89) respectively. It was found that there is a statistically significant interaction between drying method and pretreatment. The maximum (33.96) ($P_3 \times T_1$) shows the maximum a* value where and tray drying ($P_3 \times T_3$) had the lowest value (11.33).

The colour parameter (a*) is given in Table no. 2 that ranges from 11.33 to 33.96 between were significantly affected (p

$\leq$ 0.05) by both blanching duration and potassium metabisulphite (KMS) concentration. The optimized treatment resulted in higher colour values (a = 12.32) compared to the control, suggesting superior colour retention. The researchers note that extending blanching time from 0 to 3 minutes improved a* values, likely due to deactivating enzymes that cause browning. However, longer blanching periods reduced colour quality, as excessive heat led to pigment degradation. Moreover, higher KMS concentrations enhanced colour preservation by preventing browning reactions. KMS suppressed polyphenol oxidase activity, thereby limiting enzymatic browning and also interfered with non-enzymatic browning via the Maillard reaction. Consequently, the combined use of optimal blanching and KMS treatment effectively reduced both types of browning in dried mahua flowers. The similar result is noted by Pinakin *et al*. (2020) [15].

Table 2: Effect of different pretreatments and drying methods on a* colour value of mahua flower

Pre-Treatment	Colour a* value			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	22.15	28.76	12.32	21.08
P_2: Citric Acid	18.52	28.76	18.03	21.77
P_3: Control	33.96	32.40	11.33	25.90
Mean	24.88	29.97	13.89	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.61		1.84	
Drying Methods (T)	0.61		1.84	
Interaction (P × T)	1.06		3.18	

b* value for colour

The data for b* value for colour are presented in Table 3. Among the different pretreatment the significantly highest (13.71) mean b* value were recorded in pretreatment P_1 (KMS) followed by P_2 (Citric acid) (12.17) and P_3 (Control) (10.95) respectively. Among the different drying methods, the significantly highest (16.01) mean b* value were recorded in pretreatment T_3 (Tray drying) followed by T_1 (Citric acid) (12.46) and T_2 (Shade drying) (8.36) respectively. It was found that there is a statistically significant interaction between drying method and pretreatment. KMS and tray drying ($P_1 \times T_3$) having a highest b* value (17.30) while control and shade dried ($P_3 \times T_2$) sample having the lowest value (7.41) respectively.

The colour parameter (b*) is given in Table no. 3 that ranges from 7.41-17.30, respectively and were significantly affected (p $\leq$ 0.05) by both blanching duration and potassium metabisulphite (KMS) concentration. The optimized treatment resulted in higher colour values (b = 17.30) compared to the control, suggesting superior colour retention. The researchers note that extending blanching time from 0 to 3 minutes improved b* values, likely due to deactivating enzymes that cause browning. However, longer blanching periods reduced colour quality, as excessive heat led to pigment degradation. Moreover, higher KMS concentrations enhanced colour preservation by preventing browning reactions. KMS suppressed polyphenol oxidase activity, thereby limiting enzymatic browning and also interfered with non-enzymatic browning via the Maillard reaction. Consequently, the combined use of optimal blanching and KMS treatment effectively reduced both types of browning in dried mahua flowers. The result is noted by Pinakin *et al*. (2020) [15].

Table 3: Effect of different pretreatments and drying methods on b* colour value of mahua flower

Pre-Treatment	Colour b* value			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	14.50	9.34	17.30	13.71
P_2: Citric Acid	12.46	8.34	15.70	12.17
P_3: Control	10.43	7.41	15.03	10.95
Mean	12.46	8.36	16.01	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.06		0.19	
Drying Methods (T)	0.06		0.19	
Interaction (P × T)	0.11		0.33	

3.1.2 Moisture content (%)

The data for Moisture content (%) are presented in Table 4. Among the various pretreatment the significantly highest (19.95) mean moisture content (%) where recorded in pretreatment P_3 (Control) followed P_2 (Citric acid) (18.84%) and P_1 (KMS) (17.60%) respectively. Among the drying methods the significantly highest (20.60%) mean moisture content (%) where recorded in drying method T_2 (Shade drying) followed T_1 (Sun drying) (18.53%) and T_3 (KMS) (17.27%) respectively. It was shown that there was a statistically significant interaction between pre-treatments and drying techniques. Control and Shade drying (P_3T_2) had the highest moisture content (21.53), whereas KMS and Tray drying (P_1T_3) had the lowest moisture content (15.48) respectively. The data presented in the Table no. 4 indicates that the moisture content in mahua flower was 15.48 to 21.53%. The identical result was observed by Suryawanshi and Mokat (2020) [20] who reported that the moisture content of mahua flowers are ranges from 5.30 to 21.68% respectively. Mahua flower contains 15.27g / 100g of moisture in sun dried flowers reported by Mishra and Usha (2024) [12]. Pinakin *et al*. (2020) [15] reported that moisture is affected by pretreatment he stated that the increase in blanching time, a significant decrease in moisture was observed also stated that moisture content was increased with increase in citric acid concentration because citric acid is a tricarboxylic acid including hydroxyl group and both functional groups are acceptors of water molecules to form hydrogen bonding and he found 14.94 to 21.95% in wet basis.

Samples that were sun and shade dried had the highest moisture content, whereas samples that were tray dried had the lowest. This could be because tray drying uses a controlled, higher temperature to eliminate moisture faster. Deepa and Revanna (2019) [4] found that tray drying showed less moisture in drumstick leaves than sun and shade drying.

Table 4: Effect of different pretreatments and drying methods on moisture content (%) of mahua flower

Pre-Treatment	Moisture content (%)			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	17.68	19.66	15.48	17.60
P_2: Citric Acid	18.43	20.61	17.49	18.84
P_3: Control	19.48	21.53	18.85	19.95
Mean	18.53	20.60	17.27	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.08		0.23	
Drying Methods (T)	0.08		0.23	
Interaction (P × T)	0.14		0.41	

3.2 Chemical parameters of dried mahua flower

3.2.1 Alcohol soluble extractives (%)

The data for alcohol soluble extractives (%) are presented in Table 5. The significantly highest mean alcohol soluble extractive (26.56) was recorded in pretreatment P_3 (Control) followed by P_1 (KMS) (26.41) and P_2 (Citric acid) (26.17) respectively. Among the various drying methods, T_3 (Tray drying) had the greatest mean alcohol soluble extractive value (27.35%), followed by T_1 (Sun drying) (26.50%) and T_2 (Shade drying) (25.29) respectively. The interaction between pretreatment and drying method was shown to be non-significant. The data presented in the Table no. 5 indicates that the alcohol soluble extractive (%) values in mahua flower was 25.21 to 27.53% respectively. The identical result was observed by Manjula *et al.* (2021) [11] who reported that the alcohol soluble content of mahua flowers are ranges 23.58% respectively.

Table 5: Effect of different pretreatments and drying methods on Alcohol soluble extractives (%) of mahua flower

Pre-Treatment	Alcohol soluble extractives (%)			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	26.52	25.28	27.43	26.41
P_2: Citric Acid	26.22	25.21	27.08	26.17
P_3: Control	26.77	25.38	27.53	26.56
Mean	26.50	25.29	27.35	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.08		0.23	
Drying Methods (T)	0.08		0.23	
Interaction (P × T)	0.13		N/A	

3.2.2 Water soluble extractives (%)

The data for water soluble extractives (%) are presented in Table 6. Among the various pretreatment, P_3 (Control) had the greatest mean water soluble extractive value (72.05%), followed by P_1 (KMS) (71.86%) and P_2 (Citric acid) (71.54%) respectively. Among the drying methods, T_3 (Tray drying) had the significantly greatest mean water-soluble extractive value (73.59%), followed by T_1 (71.39%), while T_2 (Shade drying) had the lowest value (70.48%). The interaction between pre-treatment and drying method was shown to be non-significant.

The data presented in the Table no. 6 indicates that the water-soluble extractive value of dried mahua flowers was found to be be in range of 70.10 to 73.70% (w/w) which indicates that flowers possessed a good number of water-soluble phytochemicals, The differences observed among the treatments were found to be non-significant at the 5 per cent level, indicating that the drying and pretreatment treatments did not significantly influence the water-soluble extractive content of mahua flowers similar finding observed by Manjula *et al*. (2021) [11] in Mahua flower.

Table 6: Effect of different pretreatments and drying methods on Water soluble extractives (%) of mahua flower

Pre-Treatment	Water soluble extractives (%)			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	71.36	70.60	73.63	71.86
P_2: Citric Acid	71.09	70.10	73.44	71.54
P_3: Control	71.72	70.73	73.70	72.05
Mean	71.39	70.48	73.59	

Factors	S.Em. ±	CD at 5%
Pre-Treatment (P)	0.17	N/A
Drying Methods (T)	0.17	0.52
Interaction (P × T)	0.30	N/A

3.2.3 Total ash (%)
Table 7 shows the Mahua flower's total ash content. Out of various pretreatment P_3 (Control) had the highest mean total ash (3.95%), followed by P_2 (Citric acid) (3.94%) and P_1 (KMS) (3.92%) respectively. The different drying method with the maximum mean (4.86%) total ash was noted in T_3 (Tray drying) followed by T_2 (Shade drying) (3.58%) and T_1 (Sun drying) (3.37%) respectively.

The data presented in the Table no. 7 indicates that the total ash values of dried mahua flower were found 3.33 to 4.88(%) respectively. The similar finding was found by Manjula *et al*. (2021) [11] who reported the total ash content of mahua flower is 4.32% respectively. Total ash 0.184% of mahua flower was reported by Katiyar *et al*. (2011). Similar 3.21% average of total ash of dried mahua flower examines by the Suryawanshi and Mokat (2020) [20].

Total ash 2.96% was recorded by Pinakin *et al*. (2020) [15] in which he finds that the effect of pretreatment in which he mentioned that ash content was increased with increasing in blanching duration with KMS and decreased with increased with citric acid concentration. Total ash of dried mahua flower is 4.70% is reported by Shukla *et al*. (2024) [19].

Samples that were tray-dried had a higher total ash content than those that were sun and shade-dried. The increased ash might be the result of more moisture being removed, which would concentrate the mineral components. Deepa and Revanna (2019) [4] reported similar findings that tray-dried drumstick leaves had the highest ash level.

Table 7: Effect of different pretreatments and drying methods on Total ash (%) of mahua flower

Pre-Treatment	Total ash (%) Drying Methods			Mean
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	3.33	3.56	4.87	3.92
P_2: Citric Acid	3.38	3.58	4.85	3.94
P_3: Control	3.39	3.59	4.88	3.95
Mean	3.37	3.58	4.86	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.05		N/A	
Drying Methods (T)	0.05		0.15	
Interaction (P × T)	0.09		N/A	

3.2.4 Acid insoluble ash (%)
The data for acid insoluble ash (%) are presented in Table 8. The highest mean (2.39%) acid insoluble ash value was found in P_3 (control) of all the pretreatments followed by followed by P_1 (KMS) (2.31%) and P_2 (Citric acid) (2.18%) respectively. Among different drying methods the T_3 (Tray drying) showed the highest mean acid insoluble ash value (2.58%), followed by T_1 (Sun drying) (2.25%) and T_2 (Shade drying) (2.05%) respectively. The interaction between pretreatment and drying method was shown to be non-significant.

The data presented in the Table 4.10 indicates that the acid insoluble ash was recorded in table no which ranges from 2.00 to 2.75 (%) respectively. The similar finding was found by Raj (2019) [16] who reported the acid insoluble ash of mahua flower was 1.28±0.03%. Acid insoluble ash 0.21% of mahua flower was examines by Manjula *et al*. (2021) [11].

Ta ble 8. Effect of different pretreatments and drying methods on acid insoluble ash (%) of Mahua flower

Pre-Treatment	Acid insoluble ash (%) Drying Methods			Mean
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	2.21	2.05	2.66	2.31
P_2: Citric Acid	2.20	2.00	2.32	2.18
P_3: Control	2.34	2.08	2.75	2.39
Mean	2.25	2.05	2.58	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.11		N/A	
Drying Methods (T)	0.11		0.34	
Interaction (P × T)	0.20		N/A	

3.2.5 Total tannin content (mg/100g)
The data for Total Tannin Content (mg/100g) at 0 days are presented in Table 9. Among the different pretreatments the significantly highest (1059.86 mg/100g) mean tannin content were recorded in pretreatment P_3 (Control) followed by P_2 (Citric acid) (948.83 mg/100g) and P_1 (KMS) (906.26 mg/100g) respectively. Among various drying method the significantly highest (1078.61 mg/100g) mean tannin content were noted in drying method T_3 (Tray drying) followed by T_2 (Shade drying) (1002.33 mg/100g) and T_1 (Sun drying) (834.02 mg/100g) respectively. The interaction between pre-treatment and drying method was shown to be non-significant. The data presented in the Table no. 9 indicates that the total tannin content was ranges from 801.89 to 1206.80 mg/ 100g respectively. The similar finding was found by Raj (2019) [16] who reported the total tannin content 50.2093 ± 0.035 mg GAE/g dry weight after 72 hrs drying under control condition.

Table 9: Effect of different pretreatments and drying methods on Total Tannin Content (mg/100g) of mahua flower

Pre-Treatment	Total Tannin Content (mg/100g)			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	801.89	884.82	1032.09	906.27
P_2: Citric Acid	843.62	915.38	1087.49	948.83
P_3: Control	856.55	1206.80	1116.24	1059.86
Mean	834.02	1002.33	1078.61	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	30.35		90.87	
Drying Methods (T)	30.35		90.87	
Interaction (P × T)	52.57		N/A	

3.2.6 Total phenol content (mg/ 100g)

The data for Total Phenol Content (mg/100g) are presented in Table 10. Among the different pre-treatments with the highest (3762.80 mg/100g) mean of total phenol concentration were P_3 (Control) followed by P_2 (Citric acid) (3659.26 mg/100g) and P_1 (KMS) (3576.87 mg/100g) respectively. The different drying methods provided the highest mean total phenol content were T_2 (Shade drying) (3781.23 mg/100g) followed by T_3 (Tray drying) (3647.50 mg/100g) and T_1 (Sun drying) (3570.20 mg/100g) respectively which is non-significant.

The data presented in the Table no 10 indicates that the total phenolic content was ranges from to 3476.33 to 3888.10 mg/100g respectively. The similar to reports, the pretreatment and drying conditions have a significant impact on the total phenolic content of *Madhuca longifolia* flowers. According to Singh *et al*. (2021), Mahua flowers have an antioxidant capacity, with a total phenolic content of 25.3 ± 1.0 mg GAE/g. According to Pinakin *et al*. (2020) [15], the total phenolic content of dried Mahua flowers ranged from 307.5 to 715.1 mg/100 g, with an ideal value of 417.71 mg/100g. The processing procedures utilized prior to drying could be linked to the variance in phenolic concentration. Using the Folin-Ciocalteu method, Shukla *et al*. (2024) [19] also verified the existence of phenolic chemicals in *M. longifolia*, indicating their role in the flower's antioxidant capacity. Finding was found by Raj (2019) [16] who reported the total phenolic content 50.2093 ± 0.035 mg GAE/g dry weight after 72 hrs drying under control condition.

Preservation of phenolic chemicals during drying was significantly influenced by pretreatment. According to Pinakin *et al*. (2020) [15], the preservation of phenolic compounds in dried Mahua flowers was impacted by the interaction between KMS and citric acid and an increase in citric acid concentration had a substantial impact on phenolic content. The stabilizing impact of pH conditions, which helped shield phenolic molecules from oxidative destruction during drying, was responsible for the increase in phenolic content after citric acid pretreatment. Therefore, appropriate pretreatment can help reduce phenolic losses and preserve the antioxidant properties of dried Mahua flowers, especially when KMS and citric acid are used together.

The drying method impacted the total phenol content. Microwave drying yielded the highest value, however shade drying had a higher phenol content than sun and tray drying. This suggests that phenolic compound retention was impacted by drying conditions. Kaur *et al*. (2024) [8] observed similar findings in maize silk, with phenol contents of 1243.34, 1126.93and 1199.70 mg GAE/100 g in shade, sun and tray drying, respectively.

Table 10: Effect of different pretreatments and drying methods on Total Phenol Content (mg/100g) of mahua flower

Pre-Treatment	Total Phenol mg /100g			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	3476.33	3676.54	3577.73	3576.87
P_2: Citric Acid	3558.24	3779.05	3640.49	3659.26
P_3: Control	3676.05	3888.10	3724.26	3762.80
Mean	3570.20	3781.23	3647.50	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	173.24		N/A	
Drying Methods (T)	173.24		N/A	
Interaction (P × T)	300.07		N/A	

3.2.7 Total flavonoid content (mg/100 gm)

The data for Total Flavonoid Content (mg/100g) are presented in Table 11. Among the various pre-treatments with the highest (2242.53 mg/100g) mean flavonoid concentration were noted in P_3 (Control) followed by P_2 (Citric acid) (2123.49 mg/100g) and P_1 (KMS) (1975.86 mg/100g) respectively. The highest mean of total flavonoid content (2492.51 mg/100g) was observed in T_2 (Shade drying) among all drying methods followed by T_3 (Tray drying) (2108.77 mg/100g) and T_1 (Sun drying) (1740.59 mg/100g). The interaction between pre-treatment and drying method was shown to be non-significant.

The data presented in the Table no. 11 indicates that the total flavonoid content was ranges from to 1576.70 to 2225.02 mg/ 100g respectively. *Madhuca longifolia* flowers were found to have a total flavonoid content of 25.3 ± 1.0 mg GAE/g FW. This shows that flavonoid compounds are present in significant amounts and contribute to the antioxidant capacity of Mahua flowers. Singh *et al*. (2021) reported similar results and Shukla *et al*. (2024) [19] used the Folin-Ciocalteu method to confirm that *M. longifolia* contains phenolic chemicals.

Mahua flowers have a total flavonoid content ranging between 1761 and 2752 mg/100g. Citric acid pretreatment may help preserve the stability of flavonoid molecules by lowering their susceptibility to oxidation in acidic circumstances, as evidenced by the fact that the flavonoid content increased with increasing citric acid concentration according to Pinakin *et al*. (2020) [15] and similar results, noting that mahua flowers flavonoid content increased as the concentration of citric acid increased during pretreatment. This improvement was credited by the authors to the protective impact of acidic environments on the stability of flavonoids.

The content of flavonoids varied depending on the drying method. Microwave drying recorded the highest flavonoid content, while shade drying showed somewhat greater flavonoid content than tray drying and higher content than sun drying. According to Kaur *et al*. (2024) [8], the flavonoid concentrations for shade, sun and tray drying were 316.09, 288.21and 311.19 mg QE/100g, respectively.

Table 11: Effect of different pretreatments and drying methods on Total Flavonoid Content (mg/100g) of mahua flower

Pre-Treatment	Total Flavonoid mg /100g			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	1576.70	2392.10	1958.77	1975.86
P_2: Citric Acid	1758.12	2469.82	2142.52	2123.49
P_3: Control	1886.95	2615.62	2225.02	2242.53
Mean	1740.59	2492.51	2108.77	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	93.95		N/A	
Drying Methods (T)	93.95		281.31	
Interaction (P × T)	162.73		N/A	

3.2.8 TSS (Total soluble solids) (°Brix)

The data for TSS °Brix are presented in Table 12. Among the various pretreatment the highest (79.34°Brix) mean TSS were recorded in pretreatment P_1 (KMS) followed by P_3 (Control) (79.32°Brix) and P_2 (Citric acid) (79.19°Brix) respectively. Among different drying method the significantly highest (79.99°Brix) mean TSS were recorded in drying method T_3 (Tray drying) followed by T_1 (79.16°Brix) and T_1 (78.70°Brix). The combination of pretreatment and drying methods is indicating statistically non-significant data hence it had not affected on TSS.

The Total Soluble Solids (TSS) of mahua flower was given in Table no. 12, mean TSS ranged from 79.19 to 79.34°Brix among the pre-treatments. The highest TSS mean was recorded in KMS (79.34°Brix), followed by control (79.32°Brix), while the lowest was observed in citric acid (79.19°Brix). However, the differences among pre-treatments were found to be non-significant. The increase in TSS under KMS treatment may be attributed to the effect of blanching and pretreatment in maintaining soluble solids. The results are in accordance with Pinakin *et al*. (2020) [15], who reported that TSS of Mahua flowers was significantly influenced by blanching time, citric acid concentration and KMS concentration. They observed that blanching suppressed enzymatic activity and helped in maintaining TSS, while increasing citric acid concentration resulted in a decrease in TSS. In the present study, among drying methods tray drying recorded the highest TSS mean (79.99°Brix) followed by sun drying (79.16°Brix) and shade drying (78.70°Brix), indicating better retention of soluble solids under tray drying.

The TSS content varied based on the drying method, suggesting that the drying circumstances had an impact on the soluble solids' retention. Sun and shade drying produced relatively decreased TSS, however tray drying showed better TSS retention. Anjali and Verma (2025) [2] reported similar findings, finding that the drying process had a major effect on bitter gourd TSS retention.

Table 12: Effect of different pretreatments and drying methods on TSS °Brix of mahua flower

Pre-Treatment	TSS °Brix			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	79.32	78.68	80.01	79.34
P_2: Citric Acid	79.02	78.66	79.89	79.19
P_3: Control	79.14	78.75	80.08	79.32
Mean	79.16	78.70	79.99	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.20		N/A	
Drying Methods (T)	0.20		0.59	
Interaction (P × T)	0.34		N/A	

3.2.9 Total sugar (%)

The data for Total sugar (%) are presented in Table 13. Among the pre-treatments, P_3 (Control) had highest mean total sugar content (58.33%), followed by P_1 (KMS) (58.09%) and P_2 (Citric acid) (58.08%) respectively. The differences between pre-treatments were not significant. Among the different drying method, the significantly highest (61.31%) mean Total sugar were recorded in drying method T_3 (Tray drying) followed by T_2 (57.83%) and T_1 (55.36%). The interaction between pre-treatment and drying method was shown to be non-significant.

The Total sugar mean of mahua flower was given in Table no. 13 which ranged from 55.36 to 61.31%. The maximum total sugar content was reported in tray drying (61.31%) followed by shade drying (57.83%) while the lowest was observed in sun drying (55.36%). Among the pre-treatments the total sugar content was slightly greater in KMS treatment (58.09%) as compared with acid (58.08%) and control (58.33%) while the differences were non-significant. The findings are in agreement with Pinakin *et al*. (2020) [15] who found that blanching time, citric acid concentration and KMS concentration all had a significant effect on the total sugar content of Mahua flowers. Blanching reduced enzymatic activity and helped in maintaining total sugar content, while increasing citric acid concentration resulted in a decrease in total sugar. The substantially increased total sugar content found with KMS treatment and tray drying in the present investigation may therefore indicate improved retention of sugars during processing.

Table 13: Effect of different pretreatments and drying methods on Total sugar (%) of mahua flower

Pre-Treatment	Total sugar (%)			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	55.16	57.88	61.24	58.09
P_2: Citric Acid	55.34	57.74	61.16	58.08
P_3: Control	55.59	57.87	61.53	58.33
Mean	55.36	57.83	61.31	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.18		N/A	
Drying Methods (T)	0.18		0.54	
Interaction (P × T)	0.31		N/A	

3.2.10 Reducing sugar (%)

The data for reducing sugar (%) are presented in Table 14. Among the different pre-treatments, P_3 (Control) has highest mean reducing sugar content (45.16%), followed by P_1 (KMS) (45.12%) and P_2 (Citric acid) (44.71%). The differences between pre-treatments were not significant. Among the different drying method, the significantly highest (46.30%) mean Reducing sugar were recorded in drying method T_3 (Tray drying) followed by T_2 (44.51%) and T_1 (44.18%). The interaction between pre-treatment and drying method was shown to be non-significant.

The result presented in Table no. 14 indicates that average of reducing sugar of dried mahua flower which ranges from 44.18 to 46.30% of the drying methods. The maximum reducing sugar mean was found with tray drying (46.30%), followed by sun drying (44.50%) and shade drying (44.18%). Although there were no significant differences in the pre-treatments, the control had the highest reducing sugar concentration (45.16%), followed by KMS (45.12%) and citric acid (44.71%). The current study's results were similar to those of Suryawanshi and Mokat (2020) [20], who reported reducing sugar content ranging from 36.04 to 47.34%.

The results were similar to the findings from Pinakin *et al.* (2020) [15], who found that blanching time, citric acid concentration and KMS concentration all had significant effect on reducing sugar content in Mahua flowers. Increased citric acid concentration led to a decrease in sugar content, whereas longer blanching times increased lowering sugar due to moisture reduction and enzyme inactivation. By decreasing non-enzymatic browning, a higher KMS concentration helped in the retention of reducing sugars. Better sugar retention during drying may be the reason for the study's relatively higher decreasing sugar concentration under tray drying and KMS treatment.

Table 14: Effect of different pretreatments and drying methods on reducing sugar (%) of mahua flower

Pre-Treatment	Reducing sugar (%)			Mean
	Drying Methods			
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	44.73	44.21	46.42	45.12
P_2: Citric Acid	44.02	44.08	46.05	44.71
P_3: Control	44.78	44.24	46.45	45.16
Mean	44.51	44.18	46.30	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.25		N/A	
Drying Methods (T)	0.25		0.758	
Interaction (P × T)	0.43		N/A	

3.2.11 Acidity (%)

The data for Acidity (%) are presented in Table 15. The pre-treatments showing highest mean acidity were P_2 (Citric acid) (0.556%), followed by P_3 (Control) (0.456%) and P_1 (KMS) (0.450%). P_1 and P_3 were statistically similar while P_2 had a significantly higher value. Among the different drying methods, T_2 (Shade drying) had the highest mean (0.526%) acidity followed by T_1 (Sun drying) (0.474%) and T_3 (Tray drying) (0.461%) respectively. The interaction between pre-treatment and drying method was shown to be non-significant.

The result presented in Table no. 15 indicates that mean of acidity of dried mahua flower which ranges from 0.461 to 0.526% mean of the drying methods. The maximum mean of acidity concentration was found with shade drying (0.526%), followed by sun drying (0.474%) and tray drying (0.461%). Although there were no significant differences in the pre-treatments, the citric acid had the highest mean of acidity concentration (0.556%), followed by control (0.456%) and KMS (0.450%) respectively.

The titratable acidity of dried mahua flowers was influenced by the type of pretreatment. The higher acidity observed in citric acid-pretreated samples compared with KMS-pretreated samples may be attributed to the acidic nature of citric acid and its direct contribution to the titratable acid content of the dried product. Similar observations were reported by Sharma *et al*. (2015) [18] in dried sweet bell pepper (*Capsicum annuum*), where different chemical pretreatments were applied before dehydration. The authors recorded titratable acidity of 1.42% and 1.65% in samples pretreated with 0.3% and 0.6% citric acid, respectively, whereas the samples treated with 0.25% and 0.35% KMS recorded lower acidity of 1.27% and 1.30%, respectively. The increase in acidity with increasing citric acid concentration was attributed by the authors to the addition of citric acid during pretreatment.

Table 15: Effect of different pretreatments and drying methods on acidity (%) of mahua flower

Pre-Treatment	Acidity (%) Drying Methods			Mean
	T_1: Sun Drying	T_2: Shade Drying	T_3: Tray Drying	
P_1: KMS	0.447	0.477	0.427	0.450
P_2: Citric Acid	0.523	0.620	0.523	0.556
P_3: Control	0.453	0.480	0.433	0.456
Mean	0.474	0.526	0.461	
Factors	S.Em. ±		CD at 5%	
Pre-Treatment (P)	0.009		0.026	
Drying Methods (T)	0.009		0.026	
Interaction (P × T)	0.015		N/A	

Conclusion

Based on the results of the present study, it can be concluded that different pre-treatments significantly influenced the physico-chemical and quality characteristics of mahua flowers. Among the different pre-treatments, KMS treatment with steam blanching recorded superior values for colour L*, b*, TSS, alcohol soluble extractive, water soluble extractive, TSS, total sugar and reducing sugar constituents, while citric acid treatment also showed improvement in certain properties like moisture content, total tannin content, total phenol content, total flavonoid content, total ash, acid insoluble ash and acidity. Among the different drying methods, tray drying was found to be the best drying method for mahua flowers based on its overall quality characteristics. Based on the comparative evaluation of different pre-treatments and drying methods, KMS pretreatment followed by tray drying was found to be the most suitable treatment combination for producing good-quality dried mahua flowers with better colour retention and preservation of phytochemical properties.

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