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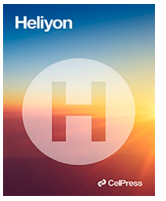

Effect of household processing on nutritional and antinutritional composition, mineral-mineral ratios, and functional properties of *Colocasia* leaves

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ABSTRACT

Colocasia leaves are high in nutrients and other phytochemicals but their utilization remains limited due to a lack of awareness. Higher content of anti-nutritional factors like oxalic and tannic acid in *Colocasia* leaves limit nutrient availability. In the present study, the effect of four household procedures viz. soaking (8–12 h), microwave heating (2–6 min), cooking (30–60 min), and blanching (1–3 min), followed by sun drying, was studied on the nutritional, antinutritional and functional properties of *Colocasia* leaves. A significant increase in crude fibre (25.7%–29.65%), and protein (4.33–15.6%) content was found in all the treatments except for the microwave treatment. A significant decrease in fat (5.7–31.4%), ash (20.34–28.22%), oxalic acid (27.07–35.32%), and tannic acid (up to 96%) was also found in various treatments. Among the minerals, a significant increase was reported for calcium (up to 16.38%), and iron (up to 5.9%). The highest mineral retention was found in soaked samples. The soaked and cooked samples also had a higher Ca: Mg ratio. A significant change in functional properties was also found. FTIR peaks suggested no significant qualitative effect occurred on phytochemical or physicochemical characteristics. Cluster analysis showed that cooking was second to soaking in terms of overall quality which were most comparable to the control. Cooking efficiently reduced the antinutritional factors, however, a significant loss of nutrients and functional properties was also observed. Therefore, the soaking of *Colocasia* leaves for 8–10 h is recommended as the best practice before their food applications.

1. Introduction

Green leafy vegetables are rich in macronutrients, micronutrients, and phytonutrients. The major macronutrients found in them are carbohydrates, proteins, and minerals [1,2]. The fat content of green leafy vegetables is comparatively low to other food sources. Among the carbohydrates, they are an excellent source of dietary fibre [2]. The major micronutrients are calcium [3], iron [4], and

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vitamin A [5]. The noteworthy phytonutrients in green leafy vegetables are ascorbic acid [6], pigments [7], and phytochemicals like polyphenols [8] and flavonoids [9]. Polyphenols of leafy vegetables include simple phenols, and phenolic acids, such as hydroxybenzoic acids [10], hydroxycinnamic acids [11], and flavonoids, such as flavones [12], flavanones [13], flavonols [14,15], flavanols [16], anthocyanins [17], etc. All these nutrients make green leafy vegetables a healthy food. The regular consumption of an adequate amount of green leafy vegetables is also reported to inhibit several life-threatening diseases like cancer [18], cardiovascular diseases [19], and diabetes [1]. Being a rich source of dietary fibre they also play a key role in weight management and control of obesity [20]. Keeping these health benefits in view, various health agencies around the globe are recommending a higher intake of green leafy vegetables. The Expert Committee of the Indian Council of Medical Research (ICMR), recommends consuming at least 50 g of green leafy vegetables and 250 g of other vegetables on a daily basis [21].

Colocasia, also known as Taro, is an orphan green leafy vegetable, whose leaves are a rich source of micronutrients viz., iron (10–11.7 mg 100 g^{-1}), zinc (0.8–4.2 mg 100 g^{-1}), potassium (0.2–1.8 g 100 g^{-1}), copper (0.8 mg 100 g^{-1}) and bioactive compounds including carotenoids, anthraquinones, caffeic acid, catechin, chlorogenic acid, coumaric acid, glucaric acid, vitexin, luteolin scoparin, shaftoside, and sinapic acid [1,22–24]. Similar to other green leafy vegetables the phytochemicals found in *Colocasia* are also responsible for critical biological activities like anti-bacterial, anti-compulsive, anti-diabetic, anti-hemorrhagic, anti-hepatotoxic, anti-hypertensive, and anti-cancerous properties [1]. The *Colocasia* leaves are also a good source of minerals of health significance like calcium, phosphorus, potassium, magnesium, iron, zinc etc [25]. The mineral-mineral ratios, especially for Ca: Mg, K: Na, and Fe: Zn, have an important role in human health. Where Ca and K have better absorption when present in double the number of their counter-minerals [26,27], a higher Fe: Zn ratio (>2:1) inhibits the absorption of zinc [26]. Colocasia leaves fulfill these desired mineral-mineral ratios and thus have the edge over other green leafy vegetables [1]. The *Colocasia* leaves are also easily available and have lower prices compared to other vegetables. This shows their potential to fulfill the demand for green leafy vegetables of the people belonging to economically weaker sections. The *Colocasia* leaves can be dried during the glut seasons of its production and can be stored for future uses. However, the higher levels of oxalic and tannic acid in the *Colocasia* leaves limit their dehydration for food applications, as the dehydration results in the loss of moisture and concentration of nutrients as well as antinutrients. The consumption of additional oxalic acid has been reported to cause stone formation in the urinary tract [28] and the higher intake of tannins is reported to decrease the efficiency of absorbed nutrients to be converted into new nutrients [29]. The treatments like soaking and cooking have been reported to reduce the oxalate and tannic acid content by leaching [28–31]. Keeping these into consideration the present study was planned to process the *Colocasia* leaves by various household methods like soaking, cooking, blanching, and microwave cooking. The present study can be beneficial to many Asian households where the consumption of packed food is comparatively less and food is generally processed/cooked at the household level.

2. Materials and methods

2.1. Collection of raw materials and process optimization

Fresh *Colocasia* leaves were procured from a household garden in Kapurthala, Punjab, India. The leaves were washed, cut into sheets of sizes 6″ × 6″, and subjected to four household procedures, viz., soaking, blanching, closed-vessel cooking, and microwave heating at different time intervals. The treated leaves were spread on a clean cloth, covered with another thin cotton cloth, and sun-dried (Table 1). The average temperature of the day was recorded to be 33 ± 4 °C, and relative humidity was 33–36%. Dried leaves were ground to a fine powder, packed in an aluminum foil, sealed, and stored in air-tight containers for further use.

2.2. Proximate analysis

2.2.1. Moisture analysis

The moisture content of samples was determined by drying them in a hot air oven at 70 °C until constant moisture was achieved [32]. The formula used for the calculation of percent moisture was as follows:

$$\text{Moisture content } (\%) = \frac{\text{Weight of the sample before moisture extraction} - \text{weight of the sample after moisture extraction}}{\text{Weight of the sample taken for moisture extraction (g)}} \times 100 \quad (1)$$

Table 1
Sample codes for the treatment-time combinations.

Sample code	Treatment	Sample code	Treatment
C	Control	C30	Closed vessel cooking for 30 min
S8	Soaking for 8 h	C45	Closed vessel cooking for 45 min
S10	Soaking for 10 h	C60	Closed vessel cooking for 60 min
S12	Soaking for 12 h	B1	Blanching for 1 min
M2	Microwave heating for 2 min	B2	Blanching for 2 min
M4	Microwave heating for 4 min	B3	Blanching for 3 min
M6	Microwave heating for 6 min		

2.2.2. Crude protein

The crude protein was determined by N/Protein Analyzer (Flash 2000, Thermo Scientific, IN) which works on the Dumas principle. The Dumas principle relies on the quantitative conversion of nitrogen present in the sample into gaseous nitrogen oxides by the complete combustion in a furnace maintained at 950–1100 °C. The nitrous oxides are then reduced into nitrogen and are quantified with a thermal conductivity detector [33].

$$\text{Crude protein } (\%) = \text{Percent nitrogen} \times 6.25 \tag{2}$$

2.2.3. Crude fat

The fat was measured using Soxtec (Quesst International, Bangalore) equipment. Preweighed moisture-free samples were put into a thimble and were extracted with petroleum ether at 60–80 °C. On the completion of extraction, the solvent was recovered by evaporation, fat weight was measured, and further converted into percentages putting the values in the formula [34].

$$\text{Fat } (\%) = \frac{\text{Weight of fat (g)}}{\text{Weight of sample (g)}} \times 100 \tag{3}$$

2.2.4. Ash estimation

For the ash estimation, 5 g of sample was taken in a silica crucible, charred on an open flame to the point the black smoke ceases to come out and the charred sample was further put in a muffle furnace maintained at 550 °C for 6 h. On cooling the weight of ash was measured and the percent ash was measured by putting the values in the formula [34].

$$\text{Ash } (\%) = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100 \tag{4}$$

2.2.5. Total carbohydrates

Total carbohydrates were determined using the subtraction method [35]. The formula is as follows:

$$\text{Total carbohydrates } (\%) = [100 - (\text{moisture content } (\%) + \text{fat } (\%) + \text{protein } (\%) + \text{ash } (\%)] \tag{5}$$

2.2.6. Crude fibre

The crude fibre was determined using Fibertec (Foss instrument, Sweden) instrument. One gram of fat and moisture-free sample was extracted by boiling for 30 min in 150 mL of 1.25% of sulphuric acid, followed by rinsing thrice with hot water (90–100 °C) for 3–5 min, again extracting with 1.25% sodium hydroxide, and repeating the rinsings with hot water. The acid and alkali extracted sample was soaked in acetone solution for 3 min, after which the excess acetone was removed and the extracted sample was dried in a hot air oven maintained at 130 ± 2 °C for 2 h. The weight of the dried sample was measured and it was then placed in a muffle furnace maintained at 550 ± 2 °C for 5 h. The weight of ash was measured and the results were put into a formula to calculate the crude fibre content [34].

$$\text{Crude fibre } (\%) = \frac{\text{weight of oven} - \text{dried sample after acid and alkali extraction (g)} - \text{weight of ash sample(g)}}{\text{Weight of sample taken for fibre estimation (g)}} \times 100 \tag{6}$$

2.3. Antinutritional factors

2.3.1. Tannins

Tannins were extracted by the procedure described by Saxena et al. [36]. A precisely weighed (0.5 g) sample was boiled with 75 mL of water for 30 min, after which the mixture was centrifuged for 20 min at 492×*g*, and the supernatant was collected, and the final volume was made to 100 mL with distilled water. From this extract, 1 mL was transferred to a 100 mL volumetric flask containing 75 mL water. To this, 5 mL of Folin-Denis reagent and 10 mL of sodium carbonate solution were added and diluted to 100 mL with distilled water. The mixture was shaken well and kept for 30 min and the absorbance was recorded at 700 nm. The tannin content of the aliquot was measured in Tannic acid equivalent (TAE) by putting the OD value of the sample in the standard curve. The tannin content of the sample was further calculated by putting the values in the formula.

$$\text{Tannin content } (\%) = \frac{\text{Tannin content from the standard curve (g)} \times \text{Dilution factor} \times \text{Volume made up}}{\text{The volume of the sample taken for estimation} \times \text{Weight of the sample taken}} \times 100 \tag{7}$$

2.3.2. Total oxalic acid

For the extraction of oxalic acid, a 6 g sample was homogenized with 100 mL distilled water, and diluted with HCl in a ratio of 2:10. To this mixture, 2 drops of capryl alcohol were added and it was boiled for 15 min. The mixture was cooled, shaken, and set aside overnight. The following day, it was filtered, and 25 mL of filtrate was taken in a flask and to this 5 mL of phosphoric tungstate, the reagent was added. The mixture was left undisturbed for 5 h and then centrifuged at 1107×*g* for 10 min. From this, 20 mL of clear solution was taken and transferred to a 50 mL centrifuge tube. To this ammonium hydroxide was added dropwise until the precipitates of phosphotungstate were formed. Further, 5 mL of calcium chloride reagent was added to it and it was stirred with a glass rod. The

solution was left overnight in a refrigerator at 5–7 °C and the next day it was centrifuged for 10 min at 1107×*g*, and the supernatant was removed. The precipitates were dissolved in 5 mL of 10% sulphuric acid; the test tube was placed in a water bath at 100 °C for 2 min and then titrated against 0.02 N potassium permanganate [37].

1 mL of 0.02 N potassium permanganate = 0.00090 g oxalic acid (8)

2.4. Mineral content

Mineral content was determined by thermo electron inductively coupled plasma atomic emission spectrometry (ICP-AES). One gram of dry sample was taken in a conical flask and 10 mL of diacid [Nitric acid + Perchloric acid (3:1)] was added and left overnight [38]. Then, the mixture was digested until white fumes were observed. The digested sample was cooled and its volume was made to 25 mL with double distilled water and was further used for mineral analysis. The content for each mineral obtained in ash was expressed per 100 g of sample.

2.5. Functional properties

To determine oil absorption capacity (OAC), vegetable oil (10 mL) was added to a 1 g sample in a test tube and mixed with the help of a magnetic stirrer [39]. The mixture obtained was centrifuged at 1509×*g*. The oil absorbed was expressed as the percent of oil bound by a 100 g sample on a g/g basis. The water absorption index (WAI) and water solubility index (WSI) were determined using the method of Beuchat [40]. The water activity of uncooked samples was measured using a water activity meter, and samples were tested in three replicates.

2.6. Fourier transform infrared spectroscopy (FTIR) analysis

For the qualitative analysis, spectra of the dried samples of control as well as the treated *Colocasia* leaves were determined using FT-IR (Shimadzu 8400S FTIR Spectrometer, equipped with potassium bromide beam splitter). Pre-weighed sample (5 mg) was taken along with 5 mg KBr and 40 scans were obtained at a mid-infrared range of 4000–500 cm^{-1} and resolution of 4.0 cm^{-1}. Before filling the sample, the attenuated total reflection (ATR) plate was cleaned with analytical grade isopropyl, followed by drying. The spectra were obtained in terms of wavenumber vs. transmittance. The interpretations of the results were made as per the guidelines given by Stuart [41].

2.7. Measurement of color

Color is an important determinant for the acceptability of leafy vegetables [42,43]. The color of *Colocasia* leave samples was determined using CM-5 spectrophotometer (Konica Minolta). 4 strands of each sample were taken to analyze color. The values for color were reported following the CIELAB color system, where L*, a*, and b* represents lightness, redness (+)/greenness (−), and yellowness (+)/blueness (−), respectively. From the values obtained, ΔL*, Δa*, Δb*, ΔE* (total color difference), ΔC* (difference in chroma), and ΔH* (difference in hue angle) were calculated.

2.8. Statistical analysis

SPSS Statistics 25.0 (IBM, NY, USA) was used to analyze the data for variance (one-way ANOVA), and mean comparisons were done

Table 2
Effect of household procedures on proximate composition of Colocasia leaves.

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Total Carbohydrate (%)	Crude fiber (%)
C	8.66 ± 0.10^{c}	20.07 ± 1.01^{b}	5.79 ± 1.20^{e}	13.96 ± 2.39^{b}	51.52 ± 3.95^{b}	12.14 ± 0.64^{a}
S8	8.22 ± 0.36^{ab}	24.36 ± 0.70^{f}	4.58 ± 0.72^{de}	10.42 ± 0.26^{a}	45.51 ± 1.43^{a}	15.14 ± 0.65^{bc}
S10	8.21 ± 0.25^{ab}	22.31 ± 0.76^{de}	5.21 ± 0.28^{e}	10.40 ± 0.15^{a}	47.35 ± 0.81^{a}	14.73 ± 0.34^{b}
S12	9.26 ± 0.23^{d}	22.23 ± 0.76^{cde}	4.76 ± 0.32^{de}	10.37 ± 0.42^{a}	47.38 ± 0.75^{a}	15.26 ± 0.82^{bc}
M2	8.53 ± 0.09^{bc}	18.54 ± 0.52^{a}	3.57 ± 0.79^{cd}	10.55 ± 0.08^{a}	60.67 ± 0.37^{h}	12.93 ± 0.64^{a}
M4	8.52 ± 0.13^{bc}	18.16 ± 0.50^{a}	3.05 ± 0.62^{bc}	10.54 ± 0.13^{a}	59.20 ± 1.14^{gh}	12.40 ± 0.40^{a}
M6	8.44 ± 0.10^{abc}	18.30 ± 0.75^{a}	1.72 ± 0.16^{a}	11.02 ± 0.33^{a}	56.19 ± 050^{ef}	12.33 ± 0.34^{a}
C30	8.68 ± 0.37^{c}	23.10 ± 0.46^{ef}	3.77 ± 0.26^{cd}	10.36 ± 0.34^{a}	54.10 ± 0.58^{bcde}	14.78 ± 0.33^{b}
C45	9.55 ± 0.24^{d}	22.89 ± 1.09^{ef}	2.71 ± 0.28^{bc}	10.95 ± 0.30^{a}	51.91 ± 1.87^{bc}	15.13 ± 0.07^{bc}
C60	9.62 ± 0.22^{d}	24.02 ± 0.28^{f}	1.97 ± 0.64^{ab}	11.12 ± 0.30^{a}	53.26 ± 0.80^{bcd}	15.74 ± 0.18^{c}
B1	8.19 ± 0.21^{ab}	20.94 ± 0.41^{bc}	5.46 ± 1.21^{e}	10.23 ± 0.29^{a}	55.18 ± 1.68^{def}	12.10 ± 0.21^{a}
B2	8.08 ± 0.18^{ab}	21.08 ± 0.94^{bcd}	4.89 ± 0.17^{de}	10.24 ± 0.30^{a}	57.71 ± 1.37^{fg}	12.19 ± 0.25^{a}
B3	8.06 ± 0.37^{a}	23.20 ± 0.70^{ef}	3.97 ± 0.87^{cd}	10.23 ± 0.32^{a}	54.54 ± 1.55^{cde}	12.49 ± 0.17^{a}

Values are means ± SD of 3 replications. Different superscripts in a column indicate that they are significantly ($p \leq 0.05$) different from each other determined by Duncan's tests.

using Duncan's Multiple Range Test. Pearson's correlation coefficient was used to understand the relation between different variables. Significance was accepted at $p \leq 0.05$. The data were standardized for hierarchical clustering for different scale usage with the Ward method.

3. Results and discussion

3.1. Proximate composition

Fresh untreated *Colocasia* leaves had a moisture content of 82.63% ± 2.56 and the moisture of dried leaves powder was reduced to 8.66% ± 0.10. A significant increase in moisture content (6.93%) was recorded with an increase in soaking time ($p \leq 0.05$) (Table 2). An increase in cooking time to 60 min also increased the moisture content by 11.08%. This increase in the moisture content in soaked and cooked leaves might be attributed to the change in cellular structure, leading to increased water absorption [44]. In contrast, the blanching and the microwave heating treatments decreased the moisture content by 6.92% and 2.54%, respectively. The protein content was increased (4.33–15.6%) on soaking, cooking, and blanching while a decrease was observed in microwave cooking. The increase in protein content on soaking, cooking, and blanching might be due to the loss of soluble nutrients, which in turn increased the overall percentage of protein. Another possibility for the increased protein content might be the increased availability of free protein upon the breakdown of complex cellular structures into simpler ones [44]. A decrease in the protein content of milk has been reported when treated with microwaves above 50 °C [45]. The decrease in fat content (5.7%–31.4%) of *Colocasia* leaves were also found in all the treatments. The minimum loss in fat content was observed in soaking and blanching. An increase in soaking and blanching time was also found to increase fat loss. Microwave treatment reduced the fat content significantly. This might be because microwave heating increases the content of free fatty acids and promotes lipid oxidation [45]. Grewal et al. [46] have also reported the loss in fat content of milk on microwave heating. A linear decrease in the fat content of *Colocasia* leaves was also observed in cooking (Table 2). Similar results were reported by Asmaa et al. [47] for chicken sausage where the superheated steam cooking of chicken sausage for 2–6 min linearly reduced its fatty acids content with an increase in time and temperature. Significant (20.34–28.22%) losses in the ash content were found in the initial treatments of soaking, microwave heating, cooking, and blanching. There might be a loss of some soluble fractions of minerals on soaking, cooking, and blanching. Kimura and Itokawa [48] reported an average 30–40% loss of minerals in cooked vegetables compared to uncooked vegetables. Kumar et al. [49] also reported some losses in mineral contents of *Dolichos lablab* beans on microwave cooking. The total carbohydrate content was determined by the subtraction method, hence, its results were affected by all other parameters. The fiber content of the soaked as well as cooked samples was increased by 25.7% and 29.65%, respectively. A similar study conducted on cowpea pods also reported increased fiber content (30–38%) upon pressure cooking [50]. Another study conducted on pumpkin leaves reported a 24.6% increase in crude fibre on boiling [51]. The increase in fibre content might be due to the increase in amylase activity, loss of soluble sugars and minerals, and reduction in phytates on soaking [52].

3.2. Antinutrients

The high concentrations of non-nutritive compounds like tannic acid, and oxalic acid exhibit an inhibitory effect on minerals and are hence termed anti-nutrients. In the control sample, both oxalic and tannic acids were present in high concentrations (741.40 ± 1.05 mg 100 g^{-1} and 93.01 ± 7.15 mg 100 g^{-1}, respectively). All the processed samples showed a decrease in total tannic acid and oxalic acid content (Fig. 1). Cooking leaves for 60 min recorded the maximum decrease in tannic acid (96.81%) concentration. In a

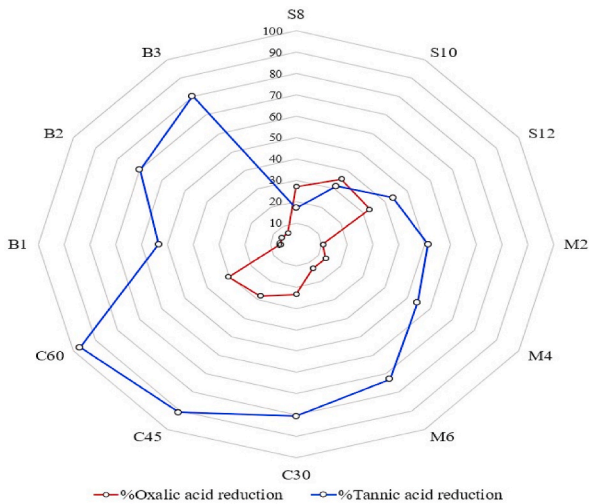

Fig. 1. Spider graph showing percent reduction oxalic acid and tannic acid concentrations, as affected by different treatment-time combinations.

study conducted on 25 traditional leafy vegetables, a mean decrease of 55.9% in tannic acid was reported upon boiling [53]. A significant decrease in oxalic acid was observed during soaking (27.07%–35.32%) and cooking (23.46%–30.24%). The decrease in tannic and oxalic acid concentrations is due to the leaching of hydrolyzable tannic acid and soluble oxalates and/or due to the changes in cellular structure [53,54]. Prolonged treatment times led to a greater reduction of anti-nutrients, and this trend was following the studies reported earlier [54,55].

3.3. Mineral content and interplay of mineral ratios

The effect of household processing methods on calcium, iron, potassium, magnesium, zinc, and sodium is given in Fig. 2. Soaking of leaves increased calcium (12.48%), and iron (5.9%) content. Cooking for 30 min also led to an increase in calcium content (16.38%), and iron (1.75%). This can be attributed to a significant decrease (33.07%) in oxalic acid concentration upon soaking [56]. In both soaking and cooking processes, there was the increased availability of free calcium in leaves, otherwise found in bound form with oxalic acid [54,55]. Oxalic acid binds with calcium and iron ions to form mineral oxalates and thus preventing their absorption [55]. A strong negative correlation between oxalic acid and calcium ($r = -0.742$, $n = 39$, $p \leq 0.01$) as well as between oxalic acid and iron ($r = -0.767$, $n = 39$, $p \leq 0.01$) also justifies the trend. However, on further cooking for 60 min a decreasing trend was observed for calcium as well as iron. Cooking of samples decreased sodium, zinc, potassium, and magnesium, because of the leaching of nutrients and change in cellular structure on heating [57,58]. Cooking is generally expected to bring about a decrease in mineral content due to leaching but the specific increase in calcium and iron in this study might be because of a reduction in oxalic acid [57].

Micronutrient ratios have a noteworthy effect on an individual's health compared to micronutrients alone. The interplay between these nutrients has been associated with cardiovascular, metabolic, and digestive health [26]. Fig. 3 represents the effect of different processing methods on the mineral-mineral ratios of the leaves. The recommended Ca: Mg ratio is 2:1, which was maintained in S10, S12, M2, C30, C45, and C60. The Ca: Mg was greater for soaked (1.53–3.69) and cooked leaves (2.5–4.5) compared to the blanched (0.5–1.5) and microwave-heated leaves (1.6–2.1). Iron and zinc present in a ratio of 2:1 or higher, have an inhibitory effect on zinc absorption [59]. It was found that all the samples i.e. control as well as the processed ones had a desirable ratio of Fe: Zn < 2:1, opposite to that of other green leafy vegetables. An optimal K: Na requires that K should be present in more than four times the amount of Na [60]. K: Na, the most important mineral-mineral ratio for cardiovascular health, was better retained in soaked (7.6–11.4) and cooked leaves (6.2–9.4). Both the microwave heated and the blanched samples had an undesirable effect on Ca: Mg as well as K: Na. Given that cooking has a detrimental impact on nutritional composition, it can be inferred that soaking is a better way of maintaining a nutritional and bioactive balance.

3.4. Functional properties

Functional parameters exhibit a significant change when a food material is subjected to physical or chemical treatments depending upon the nature of the material. Hence, it is important to test the changes in these parameters for any product development. The effect

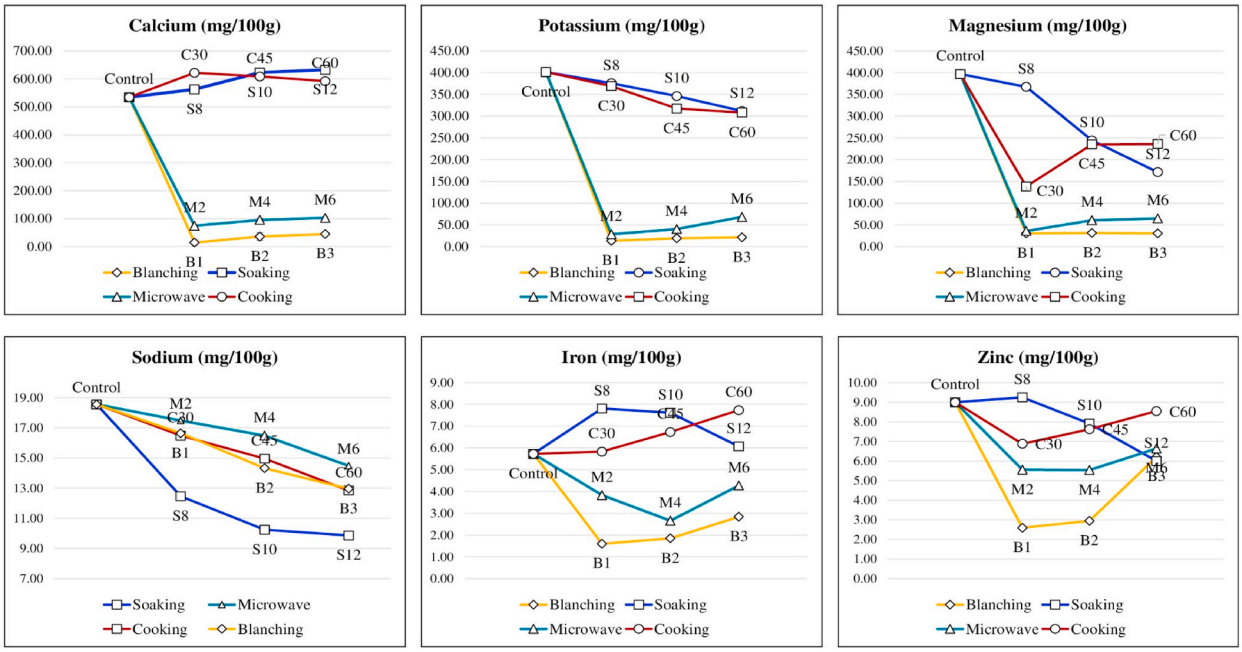

Fig. 2. Effect of household procedures on mineral concentrations.

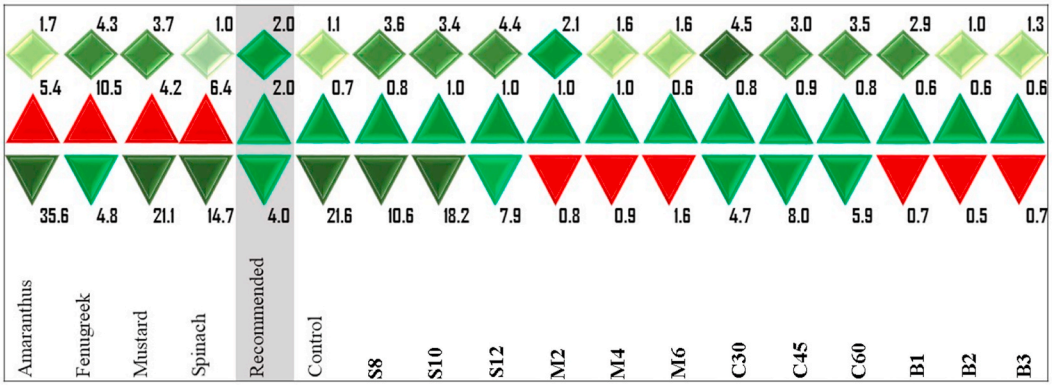

Fig. 3. Effect of household procedures on mineral-mineral ratios (Diamond = Ca: Mg; Triangle = Fe: Zn; Inverted triangle = K: Na).

of different household procedures on WSI, WAI, OAC, and a_w was determined (Table 3). The WSI was increased significantly in all the treatments. This increase might be due to the breakdown of polysaccharides into simpler molecules. Cooking has been reported to decrease the insoluble dietary fibre and increase the soluble dietary fibre due to the disruption of covalent and noncovalent bonds in the carbohydrates and protein moieties. This results in smaller and more soluble molecular fragments [61]. Pressure cooking has been also reported to decrease the content of cellulose and hemicelluloses [62]. Their breakdown increases the content of soluble fractions and this might be responsible for the increased WSI. The results of the WSI on microwave treatment are contradictory to the study conducted by Jogihalli et al. [63], where a decrease in WSI and an increase in WAI were reported on the microwave treatment. However, the trend of decrease in water solubility index with an increase in microwave treatment time is as per the trend obtained by Jogihalli et al. [63]. The decrease in WAI and OAI can also be attributed to a decrease in dietary fibre content as the dietary fibre is the major polysaccharide responsible for the absorption of water [64]. There was no significant change in the water activity content, and a positive correlation was found between moisture content and water activity of the samples ($r = 0.321$, $p \leq 0.05$, $n = 39$).

3.5. FTIR spectra

To check the qualitative effect of different treatment-time combinations, the infrared spectra of the samples were compared (Fig. 4). The area and intensities of the peaks suggested that no significant qualitative effect occurred on phytochemical or physico-chemical characteristics. The major peaks were observed in the regions of 3600–3300 cm^{-1}, 3000–2800 cm^{-1}, 2350–2300 cm^{-1}, 1700–1600 cm^{-1}, 1450–1430 cm^{-1}, 1390–1310 cm^{-1}, 1310–1250 cm^{-1}, 1250–1240 cm^{-1}, 1170–1150 cm^{-1}, 1060 cm^{-1}, 895 cm^{-1} and 790–760 cm^{-1}. The broad and strong peaks in the region of 3300–3600 cm^{-1} confirm the presence of hydroxyl (-OH) groups. C–H stretch of strong intensity in the region of 2920 and 2854 cm^{-1} shows the presence of alkanes. The weak X–H stretching near 2360 cm^{-1} represents the presence of more massive atoms such as phosphorus and silicon [41]. The absorption band in the region 1700–1600 cm^{-1} confirms the presence of amide C═O stretch. The band at 1450–1430 cm^{-1} shows aromatic P–C stretching. The bands in the range 1170–1150 cm^{-1} confirm the presence of cellulose, 1060 cm^{-1} shows the ribose stretching, and below 1000 cm^{-1} indicates the presence of various sugars. It is also observed that the spectra of the samples showed peaks on the same wavelengths but with varying intensities.

Table 3
Effect of household procedures on functional properties of Colocasia leaves.

Treatments	WSI (%)	WAI (%)	OAC (%)	a_w
C	15.00 ± 3.0^{ab}	8.61 ± 0.57^{b}	264.48 ± 3.94^{k}	0.45 ± 0.01^{d}
S8	31.67 ± 2.52^{f}	8.26 ± 1.10^{b}	177.33 ± 3.51^{h}	0.44 ± 0.00^{c}
S10	23.00 ± 2.0^{cde}	8.83 ± 0.94^{b}	191.67 ± 2.52^{i}	0.43 ± 0.00^{ab}
S12	18.33 ± 3.21^{abcd}	7.71 ± 1.21^{b}	243.33 ± 6.66^{j}	0.45 ± 0.00^{b}
M2	51.33 ± 2.52^{g}	3.42 ± 0.65^{a}	141.33 ± 3.21^{g}	0.46 ± 0.00^{def}
M4	48.33 ± 6.11^{g}	3.00 ± 1.70^{a}	73.67 ± 3.51^{f}	0.45 ± 0.00^{efg}
M6	16.67 ± 4.16^{bc}	4.44 ± 0.92^{a}	65.33 ± 6.11^{e}	0.45 ± 0.00^{def}
C30	18.00 ± 2.0^{bcd}	3.87 ± 1.41^{a}	53.67 ± 4.04^{d}	0.44 ± 0.00^{c}
C45	23.33 ± 3.51^{de}	3.47 ± 0.78^{a}	44.33 ± 4.51^{c}	0.46 ± 0.00^{fg}
C60	25.33 ± 2.52^{e}	4.07 ± 1.66^{a}	34.33 ± 3.79^{b}	0.46 ± 0.00^{g}
B1	20.67 ± 3.06^{bcde}	4.42 ± 1.67^{a}	77.00 ± 4.0^{f}	0.46 ± 0.00^{fg}
B2	33.33 ± 4.04^{f}	3.95 ± 2.66^{a}	37.33 ± 5.03^{bc}	0.45 ± 0.00^{de}
B3	66.33 ± 4.73^{h}	4.09 ± 1.03^{a}	26.67 ± 4.16^{a}	0.43 ± 0.00^{a}

Values are means ± SD of 3 replications. Different superscripts in a column indicate that they are significantly ($p \leq 0.05$) different to each other determined by Duncan's tests.

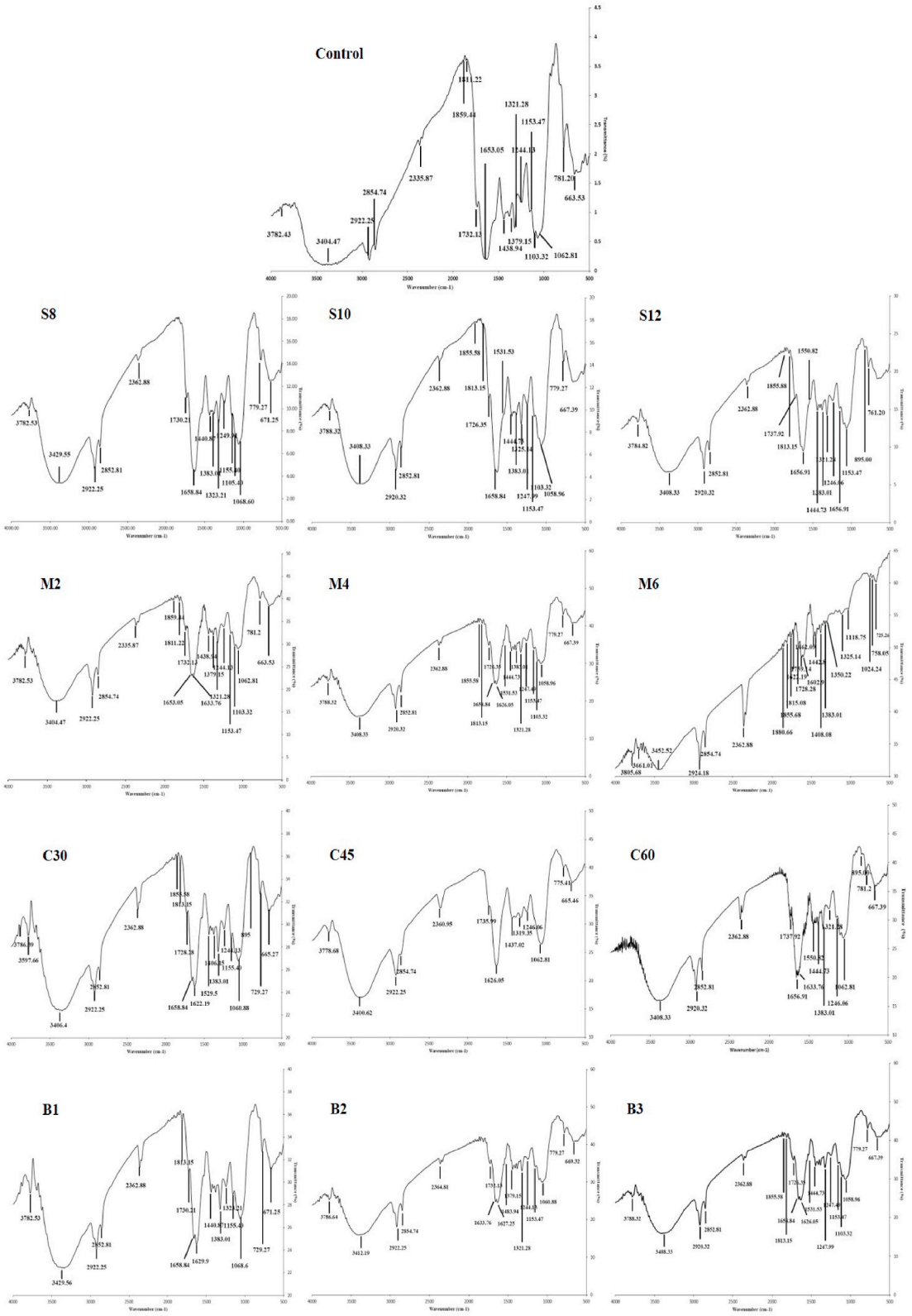

Fig. 4. FTIR spectra for control and treated *Colocasia* samples.

3.6. Cluster analysis

Cluster analysis (Fig. 5) was carried out to understand the overall effect of the different household procedures on the nutritional and functional properties of the samples. Two major clusters were formed. From cluster I, it can be observed that the soaking time of 8 and 10 h had a similar effect on the properties, which changed significantly when the time was further increased to 12 h. An increase in cooking time had an overall detrimental effect on the composition, which showed a similar trend with an increase in time. Overall, the nutritional and functional properties of soaked samples had higher similarity to that of the control. Blanching and microwave treatments (cluster II) were more similar to each other compared to the other two treatments.

3.7. Color analyses

The measurements of the surface color of the powders of *Colocasia* leaves are shown in Table 4. L*, which indicates lightness, was highest for the control sample, indicating that the leaf powder which had undergone any kind of treatment was darker in shade. A strong negative correlation was found between the L* values and the increase in soaking time ($r = -0.896$, $p \leq 0.01$, $n = 9$), and a similar was observed between the L* values and the increase in cooking time ($r = -0.866$, $p \leq 0.01$, $n = 9$). The difference in lightness, ΔL*, of the sample, was recorded highest between C60 and control (-11.42 ± 0.37). The greenness of the color indicated by negative values of a* showed a strong negative relationship with the increase in soaking time of the leaves ($r = -0.666$, $p \leq 0.01$, $n = 1$), and strong positive relation with the increase in microwaving time of the leaves ($r = 0.743$, $p \leq 0.01$, $n = 10$). The yellowness of color indicated by b* was highest for soaked samples, which did not change significantly with an increase in soaking time (25.89 ± 0.63 to 26.56 ± 0.59). Δa* indicates how much a sample is greener when compared to the control. Higher values were obtained for microwaved and blanched samples. ΔC*, which indicates chroma difference, was recorded least for the soaked samples, and no significant correlation between both was found with an increase in soaking time ($r = -0.302$, $p \leq 0.01$, $n = 9$). ΔE* was recorded highest for cooked samples ($r = 0.955$, $p \leq 0.01$, $n = 9$). Change in hue angle, ΔH* was also the least for the soaked samples. Overall, it can be concluded that the soaking of leaves showed the least change in color profile, making it acceptable for further use.

4. Conclusion

The household treatments had both positive and negative effects on the nutritional properties of the *Colocasia* leaves. The most significant results were obtained for the reduction in oxalic acid, and tannic acid, and an increase in the content of crude fibre and protein. The household treatments were also found to reduce the fat and ash content. The reduction in the antinutritional factors had a positive correlation with the increase in calcium and iron content. However, the degree of change was dependent on the type and duration of the treatment. The color losses were also found on processing and hence the longer processing times are not recommended for *Colocasia* leaves. Among the various studied treatments, the highest overall improvement in the nutritional properties was found in the soaking treatments performed for 8 and 10 h. The highest detrimental effects on the nutritional as well as the functional properties were found for the cooking treatment. The cluster analysis revealed that the soaked samples had properties most similar to the untreated sample. Hence, based on the obtained results, the soaking of *Colocasia* leaves for 8–10 h before the food application is

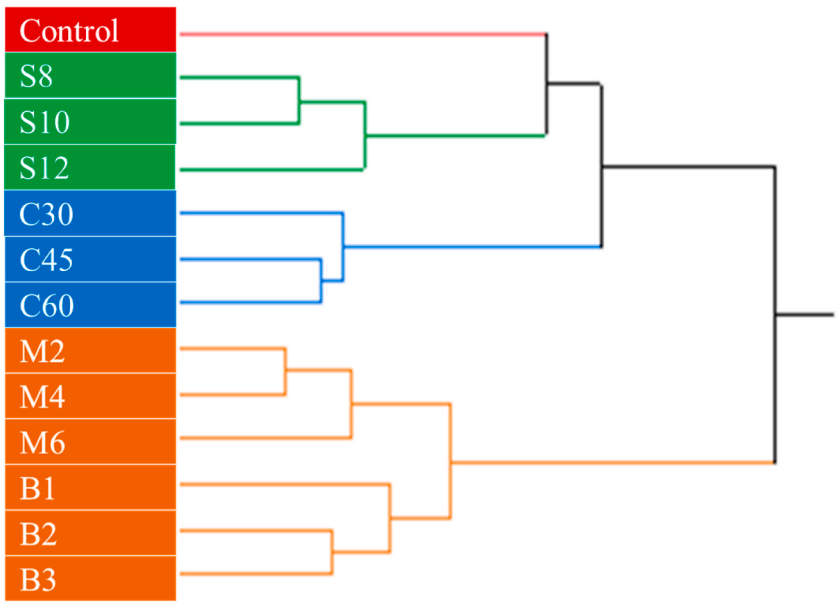

Fig. 5. Cluster analysis of various treatments.

Table 4
Effect of household procedures on color measurements of *Colocasia* leaves.

Samples	L*	a*	b*	ΔL*	Δa*	Δb*	ΔE*	ΔC*	ΔH*
C	48.04 ± 0.31^{d}	−1.30 ± 0.12^{a}	23.79 ± 0.32^{d}						
S8	47.91 ± 0.61^{d}	−0.75 ± 0.03^{ab}	26.56 ± 0.59^{de}	−0.13 ± 0.36^{d}	0.55 ± 0.14^{ab}	2.77 ± 0.48^{de}	2.84 ± 0.47^{ab}	2.83 ± 0.45^{a}	0.66 ± 0.13^{a}
S10	47.32 ± 0.47^{d}	−0.58 ± 0.07^{bc}	25.83 ± 0.63^{de}	−0.72 ± 0.78^{d}	0.72 ± 0.12^{ab}	2.04 ± 0.94^{de}	2.34 ± 1.06^{a}	2.19 ± 0.85^{a}	0.80 ± 0.11^{a}
S12	45.84 ± 0.01^{d}	−1.13 ± 0.03^{ab}	26.21 ± 0.10^{de}	−2.21 ± 0.31^{d}	0.17 ± 0.09^{a}	2.43 ± 0.22^{de}	3.29 ± 0.36^{ab}	2.43 ± 0.22^{a}	0.28 ± 0.10^{a}
M2	43.01 ± 5.32^{c}	0.29 ± 0.71^{de}	22.89 ± 6.79^{cd}	−5.04 ± 5.18^{c}	1.59 ± 0.59^{c}	−0.89 ± 6.77^{cd}	7.30 ± 5.99^{cd}	5.17 ± 3.32^{b}	1.66 ± 0.57^{b}
M4	46.02 ± 0.75^{d}	0.55 ± 0.57^{def}	27.81 ± 1.47^{e}	−2.03 ± 0.84^{d}	1.84 ± 0.69^{cd}	4.02 ± 1.41^{e}	4.87 ± 1.77^{abc}	4.43 ± 1.56^{ab}	1.90 ± 0.68^{b}
M6	46.13 ± 0.51^{d}	1.87 ± 0.70^{h}	28.95 ± 1.08^{e}	−1.87 ± 0.77^{d}	3.14 ± 0.77^{d}	5.18 ± 1.25^{e}	6.36 ± 1.49^{bcd}	6.07 ± 1.35^{b}	3.09 ± 0.72^{c}
C30	38.34 ± 0.36^{a}	−0.08 ± 0.01^{c}	15.27 ± 0.09^{a}	−9.7 ± 0.05^{a}	1.22 ± 0.12^{bc}	−8.52 ± 0.25^{a}	12.97 ± 0.20^{fgh}	8.61 ± 0.25^{cd}	0.94 ± 0.10^{a}
C45	36.97 ± 0.42^{a}	1.78 ± 0.09^{gh}	15.59 ± 0.26^{a}	−11.07 ± 0.60^{a}	3.08 ± 0.18^{e}	−8.20 ± 0.32^{a}	14.13 ± 0.34^{gh}	8.76 ± 0.36^{cd}	3.25 ± 0.18^{c}
C60	36.71 ± 0.01^{a}	1.17 ± 0.01^{fg}	14.71 ± 0.13^{a}	−11.42 ± 0.37^{a}	2.54 ± 0.01^{de}	−9.10 ± 0.31^{a}	14.82 ± 0.10^{h}	9.45 ± 0.30^{d}	2.56 ± 0.01^{c}
B1	40.89 ± 0.06^{bc}	2.58 ± 0.05^{i}	19.86 ± 0.03^{bc}	−7.16 ± 0.25^{bc}	3.88 ± 0.11^{f}	−3.93 ± 0.33^{bc}	9.04 ± 0.15^{de}	5.52 ± 0.29^{b}	4.01 ± 0.11^{d}
B2	39.37 ± 0.74^{ab}	0.58 ± 0.04^{ef}	17.30 ± 0.55^{ab}	−8.67 ± 1.00^{ab}	1.87 ± 0.14^{cd}	−6.49 ± 0.72^{ab}	11.03 ± 0.43^{ef}	6.76 ± 0.68^{bc}	1.78 ± 0.13^{b}
B3	40.59 ± 0.09^{bc}	1.74 ± 0.09^{gh}	18.32 ± 0.18^{ab}	−7.46 ± 0.29^{bc}	3.03 ± 0.17^{e}	−5.47 ± 0.20^{ab}	9.74 ± 0.23^{def}	6.25 ± 0.21^{b}	3.12 ± 0.17^{c}

Values are means ± SD of 3 replications. Different superscripts in a column indicate that they are significantly ($p \leq 0.05$) different to each other determined by Duncan's tests.

recommended as the most appropriate household treatment.

Author contribution statement

Ashwani Kumar: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
Kritika Gupta, Md. Aminul Islam Apu: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
Ghanshyam Abrol, Vidisha Tomer: Contributed reagents, materials, analysis tools or data; Analyzed and interpreted the data.

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Data included in article/supplementary material/referenced in article.

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

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