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Effect of drying temperature and maltodextrin concentration on functional properties of spray-dried Amla powder

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Abstract : Amla (Emblica officinalis) is well known for its minerals and vitamins and is one of the rich sources of vitamin C. We analyzed the effects of inlet temperature of spray dryer and maltodextrin percentage on the functional properties of amla powder. Maltodextrin is used as encapsulation material due to the higher retention potential of bioactive compounds in amla. The juice of amla prepared from freshly obtained amla fruit is subjected to spray drying with different inlet temperatures (160℃, 170℃, and 180℃) and encapsulated with maltodextrin in different concentrations as 16%, 20%, and 24%. Physicochemical parameters such as vitamin C content, antioxidant activity, total phenol content, and proximate composition were analyzed in the spray-dried amla powder. Powder properties like particle size, water activity, water solubility index, and color value were also analyzed. Therefore, from our results, we suggest that the amla powder obtained with 160℃ as inlet temperature and 24% maltodextrin concentration could be suitable to produce amla fruit beverages.

Index terms - **Emblica, maltodextrin, vitamin C, antioxidant activity, total phenol content, water activity.**

I. INTRODUCTION

Amla (Emblica officinalis) is a seasonal fruit produced in subtropical and dry climatic conditions and called amla, aonla, amalaka, nellikai, and Indian gooseberry. The fruit belongs to the Phyllanthaceae family. Vitamin C in Amla is three times higher than that of an orange. Vitamin C content of amla is 600-700mg/100gm, which itself acts as an efficient antioxidant (Kumar et al, 2012 and Khopde et al, 2001). Mineral contents include calcium, magnesium, selenium, iron, potassium, phosphorus, and zinc. Amla is used to cure diabetes, diarrhea, nausea, respiratory problems, etc. in traditional Indian medical systems including Siddha and Ayurveda (Srivasuki, 2012 and Kulkarni et al, 2018).

Since the fresh fruit is not always palatable, various products like pickles, spiced amla slices, and even ice creams and juice are prepared (Goraya and Bajwa, 2015). Combinations like grape-amla and pear-amla are widely used (Mishra et al, 2014). The spray drying technique is employed to produce amla powders which can be used to make instant drink mix and enable to reduce the size, better storage, and transport conditions. The spray drying method produces powder rapidly from any liquid sample and thermally sensitive foods are usually processed by spray dryer due to the rapid evaporation of solvents from droplets (Afoakwah et al, 2012 and Tontul et al, 2017). Parameters like concentration of encapsulation material, inlet temperature, feed flow, and characteristics are responsible for physicochemical properties like moisture content, color, solubility, etc (Muzaffur et al, 2015 and Lee et al, 2018).

For better encapsulation of vitamin C and other bioactive components and to overcome stickiness problems due to low molecular and glass transition temperature, maltodextrin was used as a drying aid (Verma et al, 2015, Sabhadinde, 2014 and Finotelli, 2005). Maltodextrin is a low-cost encapsulating agent with a high molecular weight with a D-glucose unit which reduces stickiness problems and loss of bioactive compounds while attempting to get fruit powder. Maltodextrin is used as encapsulation material due to the higher retention potential of bioactive compounds in amla.

The present study is planned to analyze the effects of inlet temperature of spray dryer and maltodextrin percentage on the functional properties of amla powder. For this, the spray-dried amla powder is subjected to analyze the different functional properties such as physicochemical parameters (vitamin C content, antioxidant activity, total phenol content) and proximate composition. Further, the powder properties like particle size by scanning electron microscope (SEM), water activity, water solubility index, and color value are also analyzed. The outcome of the study could help us to find out the optimum inlet temperature and the concentration of maltodextrin to produce the best amla fruit-dried powder that can be stored, transported, and used in any beverage.

II. MATERIALS AND METHODOLOGIES

2.1. Materials

2.1.1. Chemicals : Metaphosphoric acid, acetic acid, acetone, methanol, Folin-Ciocalteau reagent, 2,2-diphenyl picryl hydrazine (DPPH), maltodextrin, sodium carbonate, Gallic acid equivalent were purchased from Sigma Aldrich and Merck.

2.1.2. Raw materials : Raw amla of subtropical variety is purchased from the market in Chennai, India. The amla fruits are washed in running water to remove dirt and spoiled fruits were removed to avoid off-odor and ensure the quality of the powder to be prepared.

2.2. Methodologies

2.2.1. Sample preparation and spray drying

Fresh amlas are collected from the local market around Chennai, India. The fruits were washed in distilled water and reduced into small pieces, blanched for 2 minutes at 75℃, and pulverized in the mixer grinder. Juice is extracted by straining the slurry in the double-folded muslin cloth. And maltodextrin of dextrose equivalent 10 (10% w/w of dextrose) is blended at three different concentrations of 16%, 20%, and 24% with prepared juice in the mechanical stirrer for 10 mins. The process of spray drying is carried out in the lab-scale tall-type spray dryer (S.M Scientech, Kolkata, India). Three feed mixtures are processed with three different entry temperatures (160℃, 170℃, and 180℃) with a feed flow rate of 15 ml/min and the outlet temperature is observed to be 90℃. The powder is obtained by gently sweeping the drying chamber and inside the cyclone separator. The powder collected is then stored in high density polyethylene (HDPE) covers and stored for further analysis. **Figure 1** shows the flowchart of the entire process.

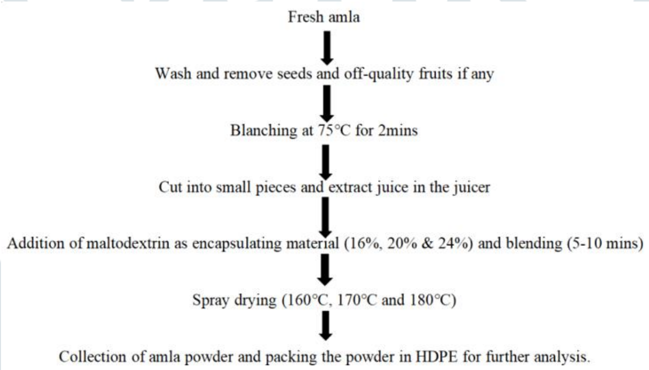

Figure 1 : Process flowchart for Spray Drying of Amla Juice

2.2.2. Powder analysis

2.2.2.1. Moisture content
Moisture percentage in the powder is analyzed by the method described in AOAC 1999, by which 3gm of the sample is dried in the hot air oven at 105℃ ± 3℃ for 3 hours and calculated by the formula in Eq. (1).

$$\text{Moisture content \%} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100 \qquad (1)$$

2.2.2.2. Water solubility index
Solubility of the powder is found by the following method. Briefly, 1 gram of the sample is mixed vigorously with 10 ml water (i.e.1:10) till the powder dissolves completely. Then the sample is centrifuged at 3000 rpm for 10 min. The supernatant is dried at 105℃ in the hot air oven and calculated by the following formula in Eq. (2).

$$\text{Water solubility index \%} = \frac{\text{weight of the supernatant after drying}}{\text{weight of the sample}} \times 100 \qquad (2)$$

2.2.2.3. Water activity
A water activity meter (LabSwift - aw, Novasina) is used to determine water activity (aw) in the powder.

2.2.2.4. Colour analysis of powder
The color of the powder is evaluated by using an instrument known as a hunter color lab (A60-1011-610). The color attributes (L*, a*, b*) are determined for color analysis.

2.2.2.5. Proximate composition
The protein content is measured using the Kjeldahl method using N×6.25 as protein factor in line with AOAC (1995) method 991.20.1, while the fat content, fibre content, and ash content are determined by AOAC (1995) method 933.05, 991.43 and 925.51A respectively, whereas the carbohydrate content is found by anthrone method.

2.2.2.6. High-pressure liquid chromatography (HPLC) analysis of ascorbic acid

Ascorbic acid present in the spray-dried amla powder is analyzed by the following method (Parbhunath et al, 2014 and Sawant et al, 2010). 5-8 grams of powder is homogenized with 60 ml of 4% metaphosphoric acid for 2 min, filtered in Whatman filter paper, and diluted up to 100ml with 4% metaphosphoric acid. Before analysis, the sample is filtered in a 0.45µm membrane filter. Standard solutions are prepared for 5 different concentrations between 50mg/L - 300mg/L. The analysis is carried out in Agilent 1260 infinity series containing C18 column (250 × 4.6 mm) with the mobile phase as 0.1% acetic acid in water: methanol (95:5 v/v) and 8mL/min and 20µl as flow rate and injection volume respectively.

2.2.2.7. Determination of antioxidant activity

Antioxidant activity is determined by the following method (Saikia et al, 2015 and Suhag e al, 2016). 200-300 mg of amla powder is mixed with 10 ml of 60% methanol. Then 2 ml of the methanolic extract is mixed with a methanolic DPPH solution of 1mM and kept in dark for 30 min at room temperature. Absorbance is recorded at 517 nm by using methanol as a blank in a spectrophotometer (UV-Vis spectrophotometer, Jacob-730ST, Japan). The antioxidant activity of the sample is calculated by the following formula in Eq. (3).

$$\text{Antioxidant activity (\%)} = \frac{\text{absorbance of control} - \text{absorbance of sample}}{\text{absorbance of control}} \quad (3)$$

2.2.2.8. Total phenolic content

Estimation of total phenolic percentage is performed in the following way (Boeing et al, 2014 and Mishraa et al, 2014). 0.5g of amla powder sample is extracted with 70% acetone followed by the addition of 0.3ml Folin-Ciocalteu reagent, 0.75ml of 20% sodium carbonate, and 4.5 ml of water to 70µl of acetone extract allowed to stand for 30 min by measuring absorbance at 760 nm against Gallic acid. Then results are found by comparing the OD value with the standard curve and expressed as gallic acid equivalent (GAE) mg/g.

2.2.2.9. SEM analysis

Morphological properties of the powder are examined by analyzing the SEM images taken at magnifications 1000X-5000X by scanning electron microscopy (carl ZEISS, Model-supra, Field Emission SEM).

III. RESULTS AND DISCUSSION

3.1. Effect of drying process on physical properties

Moisture percentage in spray-dried amla powder ranges between 2% to 7% on a dry basis which shows better storage stability of the powder. **Table 1** shows that decreased maltodextrin percentage and entry temperature increased the moisture percentage, i.e. the powder dried at 180°C has the lowest moisture content when compared to powder obtained at 160°C due to less evaporation rate at a lower temperature (Rodriguez-Hernande et al, 2005 and Samborska et al, 2015).

The water solubility index of the powder reduced with the rise in entry temperature that is the powder prepared at 160°C with 24% of carrier aid has the highest solubility percentage and the lowest is observed in powder acquired at 180°C with 16% (Jafari et al, 2017). The water activity (aw), also decreased with an increase in entry temperature and increase in maltodextrin concentration. Since water activity is responsible for microbial growth and stability, sample with 24% and 180°C has minimal water activity with longer shelf life than any other sample (Quek et al, 2007).

Table 1 : Physical properties of spray-dried amla powder

Inlet temperature (℃)	Maltodextrin %	M.C.(%)	W.S.I(%)	a_w
160℃	16%	6.45 ± 0.05	91.7 ± 0.04	0.343 ± 0.004
	20%	4.33 ± 0.02	92.87 ± 0.05	0.342 ± 0.004
	24%	4.01 ± 0.01	95.15 ± 0.02	0.270 ± 0.003
170℃	16%	4.36 ± 0.03	90.06 ± 0.03	0.341 ± 0.003
	20%	3.78 ± 0.02	92.05 ± 0.05	0.272 ± 0.002
	24%	3.27 ± 0.02	94.16 ± 0.02	0.256 ± 0.003
180℃	16%	2.35 ± 0.03	88.21 ± 0.04	0.286 ± 0.002
	20%	2.14 ± 0.03	89.33 ± 0.02	0.237 ± 0.004
	24%	2.03 ± 0.01	91.82 ± 0.03	0.232 ± 0.003

Mean± SD at P<0.05 level for triplicate data

3.2. Effect of drying process on total phenol content and antioxidant activity

Phenolic compounds act as antioxidants. Fig. 2 shows that in amla powder, phenolic content reduced with the rise in both entry temperature and maltodextrin concentration. Further, spray drying of the sample with 24% and 20% both at 170°C and 180°C respectively has no significant difference (Chong et al, 2015). In regards to the antioxidant activity, the sample obtained at 170°C with 16% has the maximum amount of antioxidant activity. **Figure 3** shows that an increase in drying temperature decreased the DPPH activity while the maltodextrin concentration negatively affected DPPH activity.

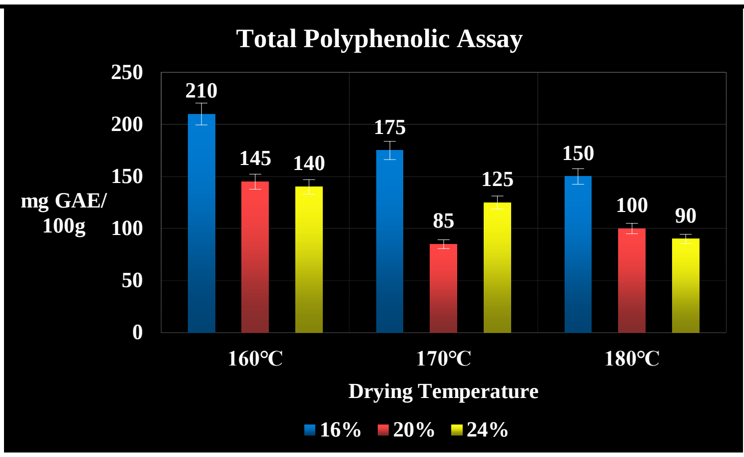

Figure 2 : Effect of drying on Total Phenol Content of amla powder

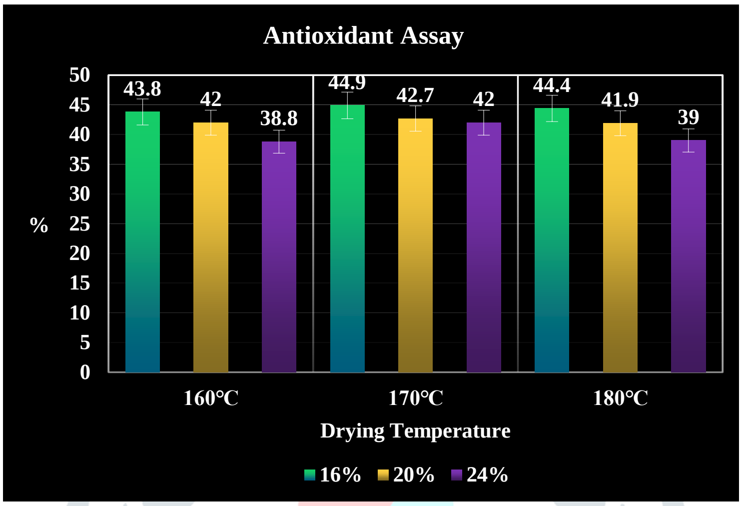

Figure 3 : Effect of drying on Antioxidant Activity of amla powder

3.3. Effect of drying on vitamin C content

Ascorbic acid percentage in amla powder is affected by the rise in both entry temperature and maltodextrin concentration. Since the vitamin is highly sensitive to both light and temperature, the highest amount of vitamin C was found in powder prepared at 160°C and 16%, while the lowest amount was observed in powder prepared at 180°C and 24%. This indicates retention of vitamin C in spray drying (Thankitsunthorn et al, 2009 and Priya et al, 2019). **Figure 4** shows that 16% maltodextrin has an appreciable amount of vitamin C (Moreira et al, 2010).

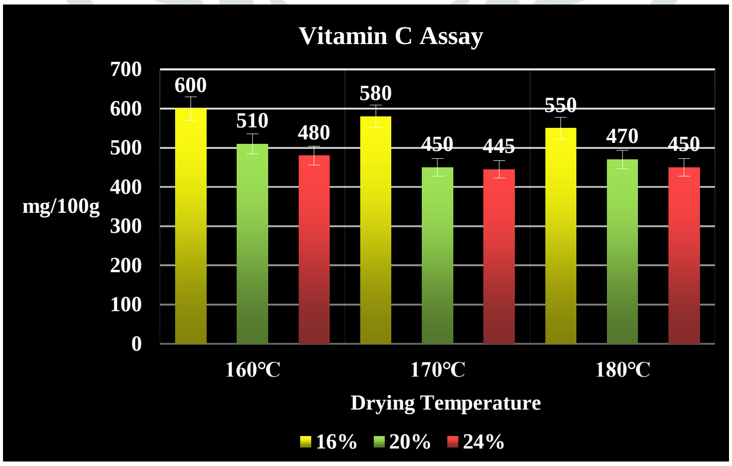

Figure 4 : Effect of drying on vitamin C content of amla powder

3.4. Proximate Analysis

Amla powder is produced with 16%, 20%, and 24% at 160°C, 170°C, and 180°C respectively. To identify which has better biochemical properties, a proximate analysis is done for these samples to know their nutrition characteristics. **Table 2** shows that the sample with 24% preparation at 160°C showed the best result of the highest content of all the proximate entities considerably.

Table 2 : Proximate compounds of spray-dried amla powder

Inlet temperature (℃)	Maltodextrin (%)	Crude protein %	Crude fat %	Crude fibre %	Total ash %	Carbohydrate %
160℃	16%	6.01±0.04	1.21±0.01	1.06±0.02	0.94±0.03	90.78±0.04
	20%	6.54±0.03	1.56±0.03	1.43±0.02	0.99±0.02	91.74±0.02
	24%	7.02±0.02	1.98±0.02	1.99±0.04	1.01±0.01	92.58±0.03
170℃	16%	7.12±0.04	0.95±0.02	0.02±0.05	0.2±0.03	80.23±0.03
	20%	7.04±0.02	1.3±0.01	0.43±0.04	0.9±0.04	89.63±0.03
	24%	7.01±0.03	1.62±0.04	0.78±0.02	1.02±0.01	91.34±0.01
180℃	16%	7.58±0.04	0.90±0.05	0.21±0.03	0.87±0.02	78.23±0.03
	20%	7.44±0.03	1.00±0.04	0.28±0.04	0.96±0.04	80.21±0.02
	24%	7.32±0.04	1.17±0.02	0.36±0.02	1.03±0.03	88.72±0.01

Mean± SD at P<0.05 level for triplicate data

3.5. Colour analysis

Colour analyses are measured in terms of L as the lightness of the sample, as (-ve is green and +ve is red), and b as (-ve is blue and +ve is yellow). **Table 3** shows that the powder with 16% at 160°C and 180°C greenness which varied from -1.09 ± 0.07 to 4.18 ± 0.31 decreased but lightness increased with an increase in inlet temperature and maltodextrin concentration. Yellowness (21.09 ± 0.19 to 25.58 ± 0.14) increased with temperature from 160°C to 180°C (Alissa et al, 2020).

Table 3 : Colour value of spray-dried amla powder

Inlet temperature	Maltodextrin%	L*	a*	b*
160°C	16%	71.67±0.04	-1.09±0.02	11.82±0.03
	20%	72.86±0.03	-1.05±0.04	16.87±0.02
	24%	74.18±0.04	-1.02±0.07	21.09±0.01
170°C	16%	82.89±0.02	-0.30±0.03	22.91±0.04
	20%	83.90±0.03	-1.09±0.01	24.62±0.05
	24%	85.47±0.05	1.01±0.01	25.06±0.04
180°C	16%	85.16±0.03	4.18±0.31	22.34±0.07
	20%	87.96±0.02	4.35±0.03	24.97±0.03
	24%	89.35±0.01	4.74±0.04	25.58±0.05

Mean± SD at P<0.05 level for triplicate data

3.6. Powder morphology

Figure 5, 6, and 7 show the SEM images taken 5000X of the dried amla powder produced at 160°C, 170°C, and 180°C accordingly. The particle size of the amla powder is not evenly distributed. A smooth surface is found in powder prepared at an intermittent concentration of maltodextrin and temperature. The smooth surface decreased with an increase in the amount of wall material and inlet temperature. And due to high temperature, particles are highly homogenized leading to the formation of complex particles.

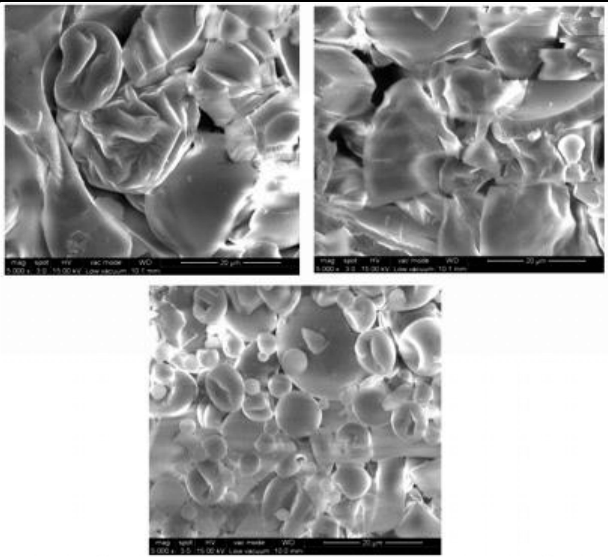

Figure 5 : Powder morphology of amla powder with 16%(A), 20%(B), and 24%(C) at 160℃.

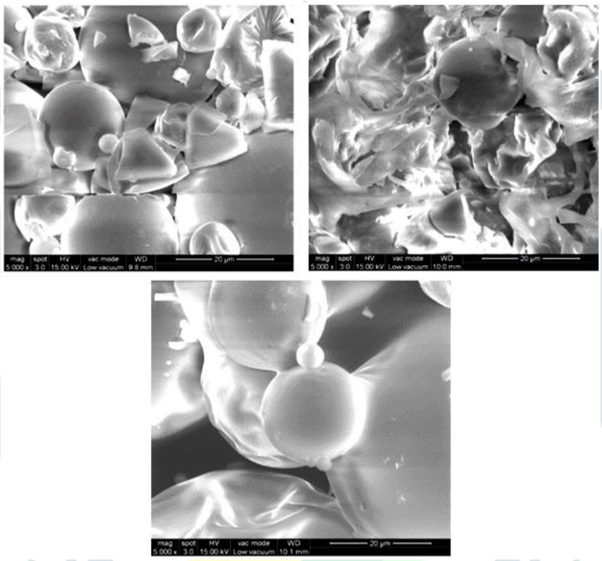

Figure 6 : Powder morphology of amla powder with 16%(D), 20%(E), and 24%(F) at 170℃.

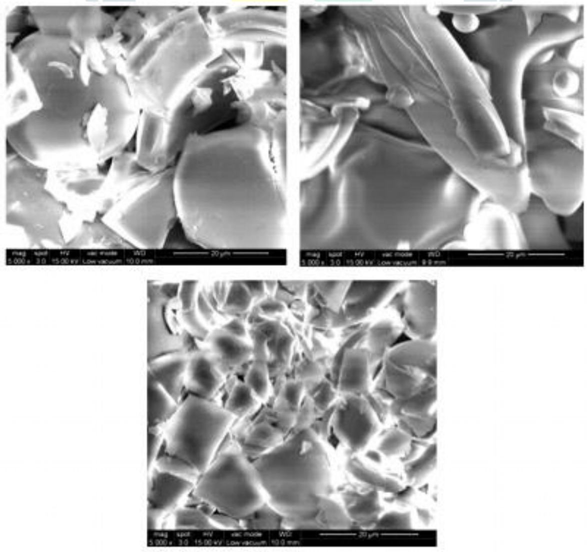

Figure 7 : Powder morphology of amla powder with 16%(G), 20%(H), and 24%(I) at 180℃.

IV. CONCLUSION

From the results of this study, vitamin C and polyphenolic content in the powder reduced to 450±0.05mg/100g and 90±0.01mg/g Gallic acid equivalent respectively with higher inlet temperature because of thermal instability of ascorbic acid at elevated temperature whereas the antioxidant activity increased to 44.4±0.04% considerably. On contrary, the proximate compounds are found to be 7.02±0.02% (crude protein), 1.98±0.02% (crude fat), 1.99±0.04% (crude fibre), 1.01±0.01% (total ash), and 92.58±0.03% (carbohydrate) which are striking high in lower inlet temperature of 160°C and 24% maltodextrin concentration. So also scrutiny of physical properties resulted that lower inlet temperatures have more water solubility 95.15 ± 0.02% and quite an acceptable value of water activity 0.270 ± 0.003 as well as moisture content 4.01 ± 0.01%. Henceforth, the overall acceptability of good quality powder sample is produced with 24% maltodextrin at 160°C which has vitamin C, polyphenolic content, and antioxidant activity of 480±0.05mg/100 g, 140±0.05 mg/g gallic acid equivalent, and 38.8±0.05% respectively.

V. CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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