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Effects of Process Parameters on the Color Quality of Anthocyanin-Based Colorants from Conventional and Microwave-Assisted Aqueous Extraction of Sweet Potato (*Ipomoea batatas* L.) Leaf Varieties †

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Abstract: The study aimed to evaluate the effects of process parameters (time and raw material weight [RMW]) of conventional (boiling for 10–45 min) and microwave-assisted (2–8 min) aqueous extraction on the color quality (*i.e.,* lightness [*L**], chroma [*C**] and hue [*H*°] of anthocyanin –based colorants of red and *Inubi* sweet potato (*Ipomoea batatas* L.) leaves. Using response surface methodology, it was found that RMW and boiling time (BT) and microwave time (MT) generally had a significant ($p < 0.05$) effect on the color quality of the extract from both extraction methods. The effects were found to be varying depending on the extraction method and variety of the leaves used. Both extraction methods produced a brown to brick red extract from the *Inubi* variety that turns red violet to pink when acidified. The red sweet potato leaves produced a deep violet colored extract that also turns red violet when acidified. It is recommended that the anthocyanin content of the extracts be measured to validate the impact of the methods on the active agent. Nevertheless, the outcomes in this study may serve as baseline data for further studies on the potential of sweet potato leaf colorants (SPLC) as colorant with functional properties.

Keywords: sweet potato leaves; anthocyanin; colorants; boiling extraction; microwave-assisted extraction; response surface methodology

1. Introduction

Color is a significant trait of sensory quality evaluation and a key attribute that affects the perception of an individual to foods [1–5]. Producers apply colorants to make food products more appealing and desirable to consumers [6,7]. Depending on the origin, colorants can be synthetic (dyes) or naturally derived (pigments) [8]. Natural colorants are more preferred because of the detrimental issues on safety and health by synthetic colorants [9,10]. Particularly, red colorants comprise the majority of commercially available colorants that are being added to foods [11]. Examples of natural red colorants include carotenoids, betacyanins and anthocyanins [12,13].

Anthocyanins are the most important water-soluble natural pigments among the group of flavonoids [14–16]. Anthocyanins are known for their excellent antioxidant properties which can protect the human body from oxidative stress thereby decreasing the risk of chronic disease such as aging, diabetes, cardiovascular diseases, and cancer [17–19]. Aside from the health-promoting benefits of these pigments, anthocyanins have a role as approved natural food colorants [20,21]. A wide range of color hues such as red, violet, purple and blue in plants like fruits, flowers, leaves, and tubers can be produced by anthocyanins at varying pH [22–24]. Natural food colorants containing anthocyanins are applied to foods and beverages such as yogurt, jellies, juices, and wine [25]. However, several problems arise when anthocyanins are exposed to various processing and storage conditions [26–29]. Factors such as pH, temperature, light, oxygen, and metal ions affect the stability of anthocyanins [14,30–32]. In a study by Bakowska-Barczak [33], it was revealed that anthocyanins with acylated substituents have increased stability to heat and light and low sensibility to pH changes. This indicates the suitability of anthocyanins as natural food colorants that can be used in the food industry [25,34–35]. Moreover, vegetable sources are more stable for food application because acylated anthocyanins are predominantly found in these commodities [23,28,36].

One of the potential sources of acylated anthocyanins is sweet potato *(Ipomoea batatas L.)*, the seventh most important food crop and the second root and tuber crop grown next to cassava [37–40]. Amongst the parts of sweet potato, the leaves contain significantly higher amounts of anthocyanins [37,41–45]. The anthocyanins in sweet potato leaf (SPL) have thepotential as natural colorants in foods [46,47] with superior shelf life and equal stability in light and heat as those in red cabbage [48,49].

In the Philippines, sweet potato is widely produced especially in the areas of Bicol region, Central Luzon, Central Visayas, and Eastern Visayas [50,51]. Numerous sweet potato varieties (i.e., *Inubi,* red, SP native) are unique in terms of leaf color [50]. The colored pigments found in SPL can be used as natural colorants to foods [34,46–47]. There are current studies on the extraction of anthocyanins and determination of phenolic content in SPL; however, there are no reports yet on the use of SPL from local varieties [52–55]. Furthermore, the potential of local SPL utilization as a source of natural colorant has been poorly noticed. The objective of the study is to evaluate the effects of process parameters (time and raw material weight[RMW]) of conventional and microwave-assisted aqueous extraction on the color quality (*i.e.,* lightness [*L**], chroma [*C**] and hue [*H*°] of anthocyanin –based colorants of red and *Inubi* sweet potato (*Ipomoea batatas* L.) leaves.

2. Materials and Methods

2.1. Sweet Potato Leaves (SPL)

Two varieties of SPL were used in the study—*Inubi* and red variety. Red and violet pigments can be observed throughout the leaf blade and veins of red SPL while those of *Inubi* SPL can only be seen on the veins [Figure 1]. *Inubi* SPL were obtained from Sapang Multipurpose Cooperative, Moncada, Tarlac, Philippines. Red SPL was procured from Fresh-Q Industries, Brgy. Sulucan, Angat, Bulacan, Philippines. Leaves were procured at the age of 3 months and transported to the laboratory where it was stored inside the chiller (~4 °C) prior to analysis.

(**A**) (**B**) (**C**) (**D**)

Figure 1. Photos of *Inubi* and red sweet potato leaves used in the study: (**A**) *Inubi* front (**B**) *Inubi* back (**C**) red front and (**D**) red back.

2.2. Extraction of Colorant from Sweet Potato Leaves

2.2.1. Conventional Extraction Method

Conventional extraction was based on the modified method of Liao et al. [56]. Pre-weighed SPL were washed repeatedly with tap water until no visible dirt can be seen. Extraction was performed by boiling SPL with 500 mL distilled water (Table 1) with occasional stirring every 5 min. After boiling, the mixture was allowed to cool at room temperature (~28 °C) for 10 min followed by initial filtration using a sieve (W.S. Tyler, Mentor, OH, USA) with mesh no. 120 to separate the leaves from the extract. The SPL extract (SPLE) was then filtered further using a Buchner filtration set-up with Whatmann No. 1 filter paper. Stabilization of the color was employed by adjusting the pH of the extract to 3 using 1% (*w*/*v*) food grade citric acid (Neco Philippines, Inc., Sta Cruz, Manila, Philippines) solution since it was reported that acid prevents the degradation of non-acylated anthocyanin pigments in the sample [57]. The obtained SPLE were stored in chilling temperature until analysis.

Table 1. Actual values of process parameters of the 14 Runs in the central composite design.

Standard Order	Block	Point Type	X_1, RMW (g per 500 mL d'H_2O)	X_2, BT (min) [a]	X_2, MT (min) [b]
1	Block 1 (Day 1)	Factorial	50.00	10.00	2.00
2		Factorial	125.00	10.00	2.00
3		Factorial	50.00	45.00	8.00
4		Factorial	125.00	45.00	8.00
5		Center	87.50	27.50	5.00
6		Center	87.50	27.50	5.00
7		Center	87.50	27.50	5.00
8	Block 2 (Day 2)	Axial	34.47	27.50	5.00
9		Axial	140.53	27.50	5.00
10		Axial	87.50	2.75	0.76
11		Axial	87.50	52.25	9.24
12		Center	87.50	27.50	5.00
13		Center	87.50	27.50	5.00
14		Center	87.50	27.50	5.00

[a] BT—Boiling time for conventional extraction, [b] MT—Microwave extraction time for microwave-assisted extraction (MAE).

2.2.2. Microwave-Assisted Extraction (MAE)

The microwave-assisted extraction (MAE) was based from Song et al., and Bhuyan et al. [55,58]. An ordinary countertop microwave oven (Whirlpool x20-20ES, U.S.A.) with fixed microwave power output of 800 W was chosen for the extraction of colorants from SPL. Pre-weighed and pre-washed SPL was placed in a 1000 mL beaker and mixed with 500 mL distilled water. The beaker was placed in the middle of the oven over a rotating dish and was exposed to microwave radiation at different times (Table 1). After heating, the beaker was left for 10 min at room temperature to cool. The extract was then filtered and acidified similar to the treatment done in the conventional extraction method.

2.3. Experimental Design and Statistical Analysess

2.3.1. Identifying the Limits of Process Parameters

The upper and lower limits of the process parameters are shown in Table 2. The minimum weight of 50 g SPL was based on the leaves to water ratio of 1:10 parts used by [59] while the maximum weight of 125 g (1:4) was based on a preliminary experiment (data not shown). The minimum and maximum time (min) of boiling was also based on another preliminary run where it was observed that shorter boiling time extracted less color from the leaves while longer boiling time resulted in the extract to dry out. The upper and lower limits of microwave time (MT) were defined by also taking into account the results obtained in preliminary tests (data not shown) as well as the significant parameters in typical MAE process for leaves [60].

Table 2. Central composite experimental design showing independent variables with actual and coded values.

Factor	Parameter	Units	Actual Values		Coded Values	
			Minimum	Maximum	Minimum	Maximum
X_1	Raw material weight (RMW)	g per 500 mL water	50	125	−1	1
X_2 [a]	Boiling time (BT)	min	10	45	−1	1
X_2 [b]	Microwave extraction time (MT)	min	2	8	−1	1

[a] For conventional extraction, [b] For microwave-assisted extraction.

2.3.2. Modeling of Responses

Different RMW-BT and RMW-MT combinations were generated using Design-Expert® Application V.7.0.0 (DX7, Stat-Ease Inc., Minneapolis, MN, USA). A central composite rotatable response surface methodology (RSM) design (Table 2) was used. Central composite RSM designs are known to be widely used for fitting quadratic or second-order response surfaces making them applicable for process optimizations [61]. Runs were separated into two blocks with each block corresponding to experimental days. Each experimental run was subjected to color measurements (L^*, C^*, $H°$). Responses were then subjected to multiple linear regression analysis to approximate empirical models, coefficient of variation (% C.V.), R-squared, and adjusted R-squared. Empirical models developed were based on the general equation for second-order responses as shown in Equation (1) where Y, β and X represents the predicted response, regression coefficients and independent variable, respectively [61,62].

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_1 X_1 + \sum_{i=1}^{n} \beta_{ii} X_j^2 + \sum\sum_{i<j=1}^{n} \beta_{ij} X_j \ , \quad (1)$$

Transformation of the models was based on the recommendation of the software based on a Box Cox Test. The most accurate model was then obtained on several statistical test performed by DX7 including F-test, lack-of-fit test, externally and internally studentized residuals, DFFITS, and Cook's Distance.

2.4. Color Measurement

The color of the sample runs were measured using a bench spectrophotometer (ColorFlexEZ, Hunter Associates Laboratory Inc., Reston, VA, USA). Approximately 35 mL of the sample SPLE was placed in the sample cup holder and the L^*, a^*, and b^* coordinates were recorded. The chroma (C^*) and hue ($H°$) values were then calculated using the obtained a^* and b^* coordinates using Equations (2) and (3), respectively.

$$Chroma(C^*) = \sqrt{a^{*2} + b^{*2}} \ , \quad (2)$$

$$Hue(H°) = \arctan\left(\frac{b^*}{a^*}\right), \quad (3)$$

The color coordinates a^* and b^* do not directly describe the quality of the color and should not be interpreted separately, hence the reason behind using C^* and $H°$ values instead [63]. An angle of 180°was added to the hue value in cases where a negative a^* value was recorded while an angle of 360°was added when a positive a^* and a negative b^* value was obtained [64]. A total of three replicates were done per experimental run and data was expressed as mean ± standard deviation (SD). Colors charts were created based on the obtained LAB coordinates using Adobe Color CC (Adobe Systems, San Jose, CA, USA).

2.5. Verification of Models

Significant models were verified by being subjected to validation experiments. Two random points were chosen from the design space and were run in triplicates. After which, the samples were again subjected to color measurements. Models were considered valid and accurate when the actual response obtained from analysis fall on the confidence and/or predicted interval of the predicted response.

3. Results

3.1. Effects of Process Parameters on the Color Quality of Anthocyanin-Based Colorants from Conventional (Boiling) Aqueous Extraction of Sweet Potato (Ipomoea batatas L.) Leaf Varieties

Statistical analyses on precision and accuracy indicate that all models can be used to predict the effect of RMW and BT on the color quality of SPLC [Table 3]. A relatively high %CV was obtained from the model showing the effect of process parameters on the hue value of red SPLC indicating that the model may not be as accurate as compared to the other models. However, the models can still be used since its adequate precision of greater than 4 means that it can be used in navigating the design space.

Table 3. Effects of conventional extraction process parameters on the color quality of SPLC.

Factor[b]	*Inubi* SPLC			Red SPLC		
	*L**	*C**	*H*°	*L**	*C**	*H*°
Constant	63.337	12.365	21.523	32.466	63.880	22.210
RMW	−0.115 [a]	0.113 [a]	0.145 [a]	−0.044 [a]	−0.124 [a]	−0.027
BT	−0.948 [a]	1.111 [a]	−0.207 [a]	−0.239	−0.666 [a]	−0.264 [a]
RMW × BT	--	-1.782×10^{-3}	--	--	2.608×10^{-3} [a]	--
RMW^2	--	2.245×10^{-4}	--	--	--	--
BT^2	0.012 [a]	−0.013 [a]	--	3.841×10^{-3}	5.214×10^{3} [a]	--
Mean	38.13	38.32	28.56	25.62	45.86	12.60
SD	2.26	2.44	2.92	1.42	0.63	3.20
R^2	0.9105	0.8770	0.8006	0.6509	0.9733	0.6356
R^2_{adj}	0.8807	0.8359	0.7608	0.5345	0.9599	0.5627
Adeq. Precision [c]	16.261	13.382	11.622	6.828	25.581	7.635
%C.V.	5.94	6.36	10.24	5.56	1.38	25.44
Lack-of-fit	0.12	0.06	0.81	0.19	0.71	0.48

[a] Significant coefficients (95% confidence level) ($p < 0.05$), [b] RMW, Raw material weight (g per 500 mL distilled water); BT, Boiling Time (min), [c] An adequate precision of greater than 4 indicates that the model can be used to navigate the design space.

Figures 2 and 3 show the contour plots and sample images with color swatches, respectively to to further demonstrate the effect of RMW and BT on the color of SPLC.

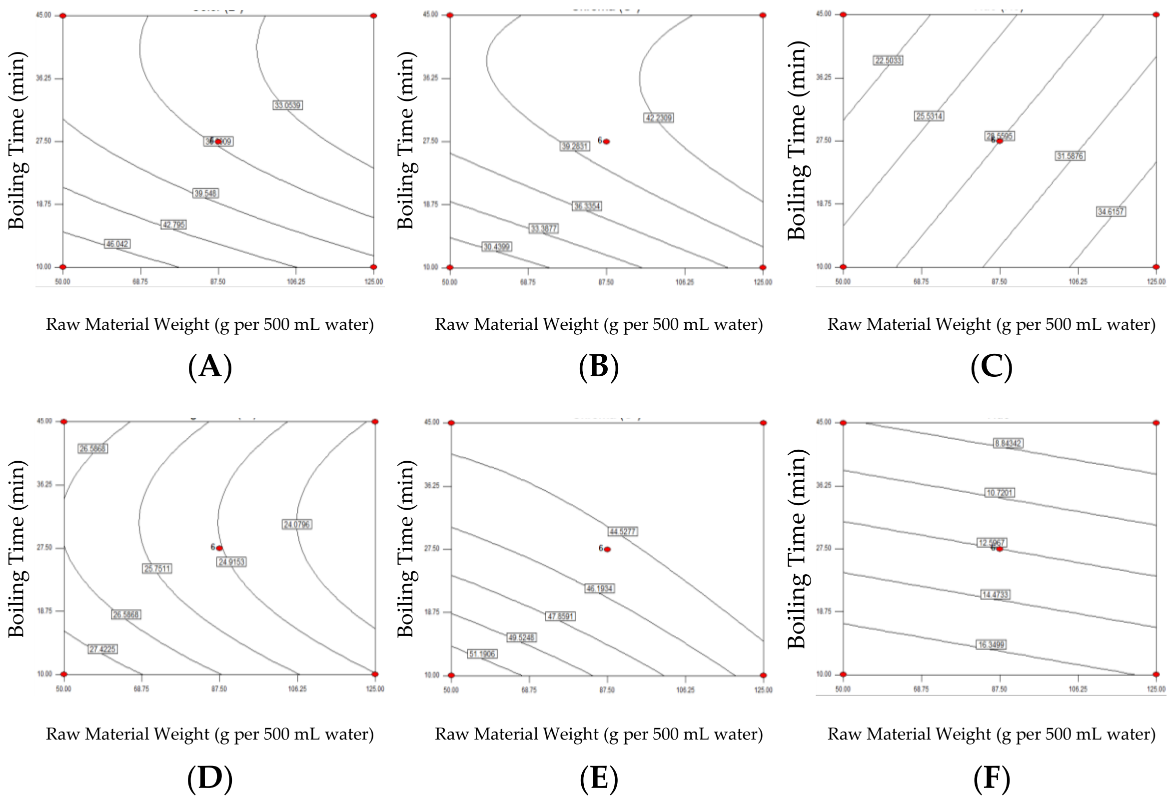

Figure 2. Contour plots showing the effect of raw material weight and boiling time on the color of *Inubi*(**A–C**) and red (**D–F**) SPLC: (From left to right) lightness, chroma and hue of SPLC.

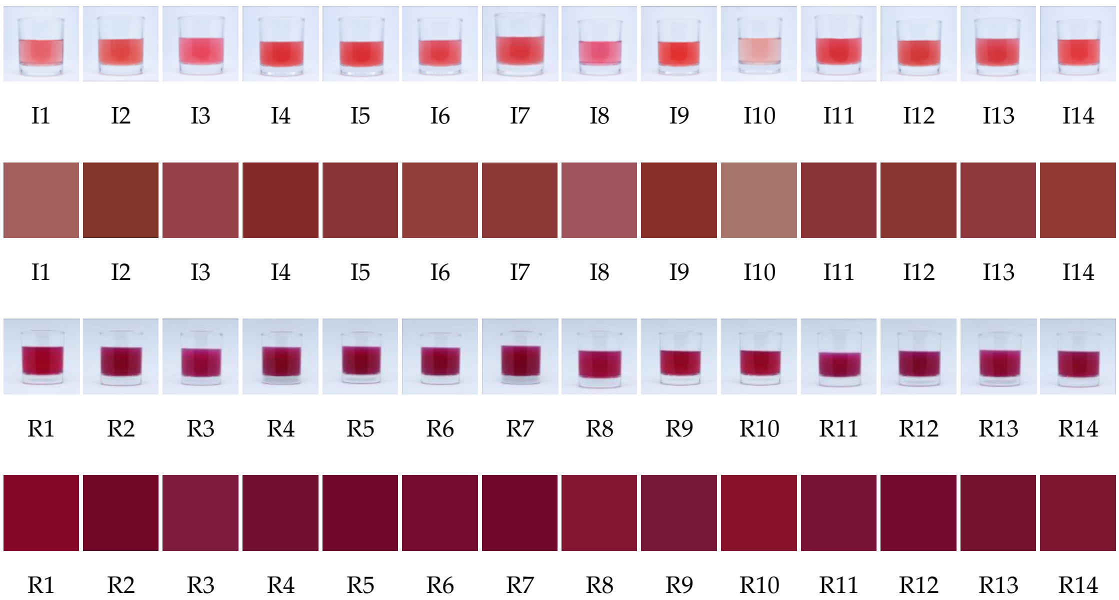

Figure 3. Actual images and color swatches of SPLC samples extracted through conventional method arranged according to standard number: (**I1–I14**) Inubi SPLC and (**R1–R14**) red SPLC.

3.2. Effects of Process Parameters on the Color Quality of Anthocyanin-Based Colorants from Microwave-Assisted Aqueous Extraction of Sweet Potato (Ipomoea batatas L.) Leaf Varieties

The effects of RMW and MT on the color quality of SPLC are summarized in Table 4. Statistical analyses on precision and accuracy indicate that all models for the color responses can be used to predict the color quality of SPLC except for the H° of red SPLC. The models were used since its adequate precision of greater than 4 means that it can be used in navigating the design space. Moreover, a relatively high %CV was obtained from the model showing the effect of process parameters on the hue value of Inubi SPLC indicating that the model may not be as accurate as compared to the other models.

Table 4. Effects of microwave-assisted extraction process parameters on the color quality of SPLC.

Factor [b]	*Inubi* SPLC			Red SPLC	
	*L**	*C**	*H°*	*L**	*C**
Constant	71.563	1.1483	−162.03	105.789	−20.354
RMW	--	-5.358×10^{-3} [a]	0.649	−0.537	--
MT	−3.731 [a]	−0.218 [a]	52.85 [a]	−14.44 [a]	22.351 [a]
RMW × MT	--	2.385×10^{-4}	0.022	-7.119×10^{-3}	--
RMW^2	--	2.000×10^{-5} [a]	-4.504×10^{-3}	3.045×10^{-3}	--
MT^2	--	0.014 [a]	−3.953 [a]	0.945 [a]	−1.620 [a]
Mean	52.91	0.27	11.48	37.77	42.56
SD	4.36	0.026	14.45	5.75	7.28
R^2	0.8272	0.9880	0.9473	0.9265	0.8902
R^2_{adj}	0.8114	0.9795	0.9097	0.8741	0.8683
Adeq. Precision [c]	15.674	28.293	13.310	11.710	14.194
%C.V.	8.25	9.62	125.80	15.23	17.11
Lack-of-fit	0.239	0.077	0.002	0.001	<0.0001

[a] Significant coefficients (95% confidence level) ($p < 0.05$), [b] RMW, Raw material weight (g per 500 mL distilled water); MT, Microwave Time (min), [c] An adequate precision of greater than 4 indicates that the model can be used to navigate the design space.

Figures 4 and 5 show the contour plots and sample images with color swatches, respectively to further demonstrate the effect of RMW and MT on the color of SPLC.

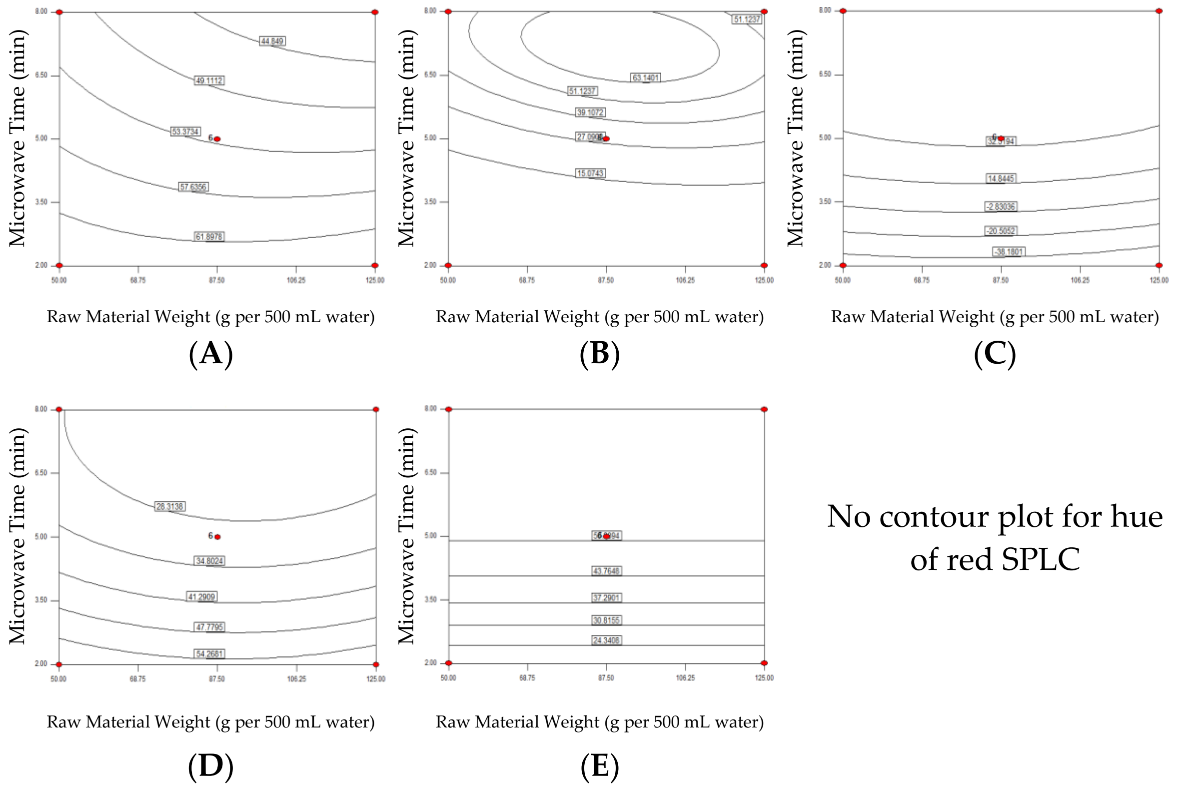

Figure 4. Contour plots showing the effect of raw material weight and microwave time on the color of *Inubi* (**A–C**) and red (**D–E**) SPLC: (From left to right) lightness, chroma and hue of SPLC.

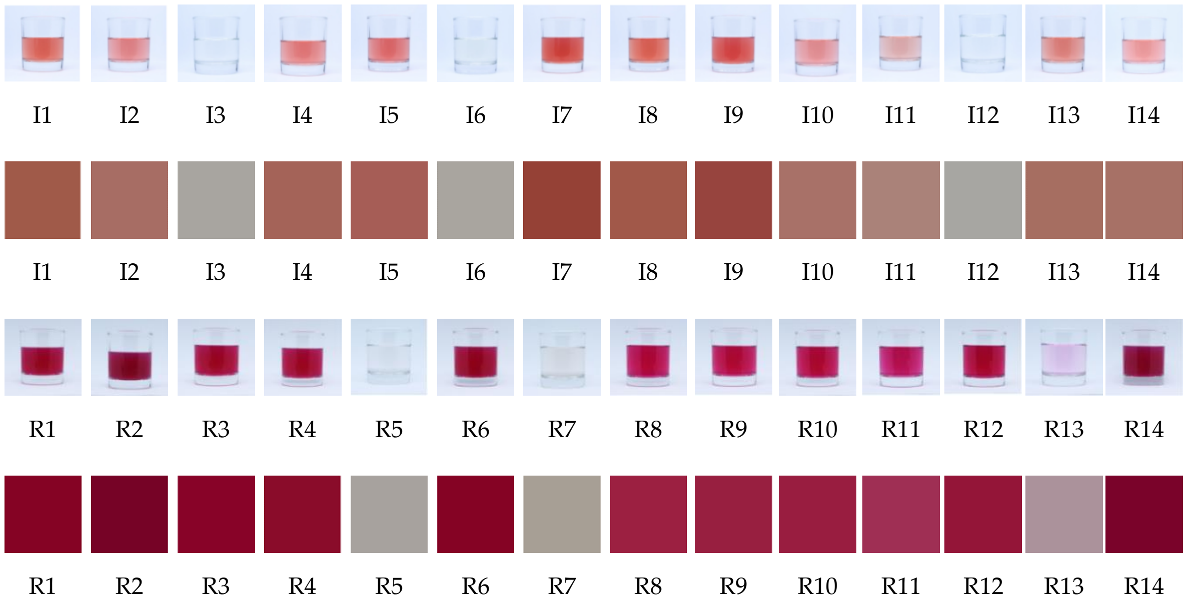

Figure 5. Actual images and color swatches of SPLC samples extracted through MAE arranged according to standard number: (**I1–I14**) Inubi SPLC and (**R1–R14**) red SPLC.

3.3. Validation of Models

Response models were validated through verification studies using random points from the design space. The results [Table 5] showed that the models can be generally used to predict the effects of RMW, BT and MT on the color quality of Inubi and red SPLC. All of the actual responses fell within the range of the prediction interval indicating that the models can accurately predict the effect of RMW and BT on color quality (i.e., lightness [L*], chroma [C*] and hue [H°]) of Inubi and red SPLC.

Table 5. Summary of the SPLE color quality model validation experiments.

Response [c]	**Conventional Extraction**		**Microwave Assisted Extraction**	
	Inubi SPLC-A[1]	Inubi SPLC-B[2]	Inubi SPLC-A[4]	Inubi SPLC-B[5]
Lightness (*L**)	35.04 ± 1.93 [b]	39.97 ± 1.89	81.23 ± 0.01 [ab]	88.01 ± 0.01 [ab]
Chroma (*C**)	41.34 ± 0.56 [b]	40.12 ± 1.91	15.46 ± 0.01	8.65 ± 0.01 [ab]
Hue (*H*°)	26.54 ± 3.71	33.38 ± 0.88 [b]	−82.14 ± 0.05 [ab]	75.15 ± 0.06 [ab]
	Red SPLC-A[2]	Red SPLC-B[3]	Red SPLC-A[4]	Red SPLC-B[6]
Lightness (*L**)	23.41 ± 0.81	23.90 ± 0.16 [b]	39.70 ± 3.71	25.00 ± 0.95
Chroma (*C**)	46.57 ± 0.20	45.08 ± 0.36 [b]	46.60 ± 4.99	49.90 ± 0.79
Hue (*H*°)	15.09 ± 0.57	8.20 ± 1.36 [b]	5.60 ± 1.47 [b]	18.60 ± 1.64

[1] Conditions: 75 g of SPL per 500 mL distilled water boiled for 20 min, [2] Conditions: 125 g of SPL per 500 mL distilled water boiled for 10 min, [3] Conditions: 50 g of SPL per 500 mL distilled water boiled for 30 min, [4] Conditions: 34.5 g of SPL per 500 mL distilled water extracted through MAE for 5 min, [5] Conditions 50 g of SPL per 500 mL distilled water extracted through MAE for 2 min, [6]Conditions 125 g of SPL per 500 mL distilled water extracted through MAE for 8 min, [a] Significantly different from the predicted value based on prediction interval, [b] Significantly different from the predicted value based on confidence interval, [c] Expressed as mean ± standard deviation.

4. Discussion

4.1. Effects of Process Parameters on the Color Quality of Anthocyanin-Based Colorants from Conventional (Boiling) Aqueous Extraction of Sweet Potato (Ipomoea batatas L.) Leaf Varieties

The RMW had significant ($p < 0.05$) negative linear effect on the lightness, L* of both red and *Inubi* SPLC implying that the sample becomes darker at increasing RMW [Figure 2A,D]. This may be due to increasing concentration of colorant extracted at increasing amount of leaves used. On the other hand, BT had a quadratic effect on the L* of both varieties of SPLC with those of *Inubi* SPLC to be significant ($p < 0.05$). This indicates that the color of SPLC continuously darkens with longer BT which then starts to increase or become lighter upon reaching the minimum L* value. The decreasing L* may be a result of the increasing pigment concentration as it is extracted from the leaves while the increasing L* value might be due to the formation of translucent extracts due to the color fading of extracted anthocyanin [65]. Moreover, increasing L* values are known to be the result of prolonged heating of anthocyanin causing it to transition from the flavylium cation to the colorless and/or yellowish carbinol [66,67].

RMW and BT also had a significant ($p < 0.05$) effect on the chroma, *C** of *Inubi* and red SPLC [Table 3]. The color of the *Inubi* SPLC [Figure 2B,E] became more saturated as observed by the increasing *C** at longer BT and greater RMW. An opposite effect was observed on the *C** value of red SPLC (Figure 2E) where the *C** value decreased with increasing RMW and BT which may be due to the differences on the variety and anthocyanin composition between the SPL varieties. The type of anthocyanin in the leaves may dictate the overall color stability of the colorant as shown in the study of the Loypimai et al., (2016) wherein cyanidin-3-*O*-glucosides anthocyanins in black rice bran colorants were found to be more thermally stable and degraded slower compared to pelargonidin and delphinidin and malvidin [68]. The opposite effect on the *C** value of red SPLC could possibly mean that the type of anthocyanin found in this SPL variety degraded much faster as compared to the anthocyanin present in *Inubi* SPLC. At prolonged BT, both varieties of SPLC eventually become less saturated which could be explained by possible degradation of monomeric anthocyanin and the conversion of flavylium cations to its colorless carbinol/yellowish form [65–67].

Figure 2C,F shows the effect of of BT and RMW on the hue (*H*°) value of SPLC. BT had a significant ($p < 0.05$) negative linear effect on the *H*° of both *Inubi* and red SPLC indicating that the color of the sample moves towards the red-violet region of the color space which is towards 0° (Lawless & Heymann, 2010). This could be a result of the increase in concentration of anthocyanin extracted due to prolonged heating and possible self-association of the pigment (Kammerer, 2016; Boulton, 2001). It could also indicate that the heating condition on the extraction of the colorant was not too severe leading to a yellow chalcone formation as demonstrated by the anthocyanin extracts of Reyes and Cisneros-Zevallos (2007). However, it was observed that RMW had different effects on the color of the two SPLC. At increasing RMW, the *H*° value of *Inubi* SPLC (Figure 2E) also increased, indicating that the color moves towards the yellow region (90°) while those of red SPLC had a decreasing *H*° (towards red). This may be due to the differences in variety of the leaves since the leaf blades of *Inubi* are predominantly green as compared to the red SPL which is predominantly purple. The green color may indicate the presence of pigments such as chlorophyll which is known to turn yellow when exposed to heat and acid (Von Elbe & Schwartz, 1996). Increasing the RMW of the *Inubi* might have resulted in the increase of chlorophyll concentration in the extract which interfered with the red color of anthocyanin. The predominant violet to red color of red SPL might indicate a higher concentration of anthocyanin which could have oppressed the possible color interference of its chlorophyll—A possible scenario that needs to be studied in future experiments.

Colors of all samples using the *Inubi* extract colors were observed to be similar having a pink, red, brown and maroon color [Figure 3]. For the red SPLC, colors were more similar and harder to be distinguished to each other having red to red-violet coloration. Comparing the LCH values of the two varieties, it was observed that red SPLC had a darker, more saturated and more red color than the *Inubi* SPL which may be due to the differences in variety of SPL used.

4.2. Effects of Process Parameters on the Color Quality of Anthocyanin-Based Colorants from Microwave-Assisted Aqueous Extraction of Sweet Potato (Ipomoea batatas L.) Leaf Varieties

Contour plots show that MT had a quadratic effect ($p < 0.05$) on *L** which implies that the color of SPLC continuously darkens with longer MT up to a certain time and beyond this period *L** values increase or become lighter [Figure 4A,D]. Contour plots [Figure 4B,E] also show that MT had a quadratic effect on *C** which implies that the color of SPLC becomes more saturated with longer MT which then starts to become less saturated upon reaching the maximum *C** value. At prolonged MT, SPLC from both varieties eventually become less saturated similar to the effect of BT in th conventional method of extraction. The increasing *C°* value may have been due to prolonged heating of anthocyanin causing the shift of flavylium ions [28,69]. This will cause self-association of the anthocyanin in the aqueous environment thereby, displacing the equilibrium towards the chalcone forms which makes the samples' color more saturated [70]. A similar trend on the effect of BT and RMW on the hue value was observed on the effect of MT and RMW during MAE [Figure 4C]. There was no generated model for the *H°* value red SPLC.

The *Inubi* SPLC using MAE have lighter pink to orange and less saturated color while the red SPLC have darker red to maroon color [Figure 5]. Some runs yielded very light-colored samples which can be attributed from the lesser RMW and shorter MT. Saturated and more red-colored samples were observed at longer MT and greater RMW similar to the conventional method.

5. Conclusions

The different process parameters showed that boiling time/micrwave time and raw material weight affected the color quality of *Inubi* and red SPLC. RMW and BT and MT generally had a significant ($p < 0.05$) effect on the color (L^*, C^*, $H°$) of both SPLC varieties. The extraction process parameters produced SPLC having colors of red, red-violet and pink. Verification experiments showed that the statistical models can accurately predict the effect of the process parameters on the quality of SPLC. The findings from the study have revealed a more in-depth analysis on the possible effects of process parameters on the extraction of anthocyanin-based colorants from sweet potato leaves. The information obtained may be useful on the possible optimization as well as exploring more on the nature of colorants found in SPLC. It is recommended that the effect of process parameters of other extraction methods on the quality of SPLC and other possible sources of anthocyanin-based colorants to be explored.

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