doi.org/10.36721/PJPS.2021.34.4.REG.1437-1444.1

Application of factorial experimental design for optimization and development of color lipstick containing antioxidant-rich Sacha inchi oil

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Abstract: This study aimed to optimize and develop the color lipstick formulation containing antioxidant-rich Thai Sacha inchi oil using full factorial experimental design. Antioxidant capacity of Sacha inchi oil was elucidated using DPPH and linoleic acid peroxidation assays. The y-tocopherol content of the oil was also determined by high-performance liquid chromatography. Developing the color lipstick, lipstick base was optimized through the variation of %Sacha inchi oil, Ozokerite and Carnauba wax ratio (O:C ratio) and %Fat. Concurrently, the influences of these factors on lipstick physical characteristics were analyzed by means of statistics. Thai Sacha inchi oil exerted a notable antioxidant capacity with the highest y-tocopherol content. The combined effect of all factors influenced on the variations of breaking point and hardness of the lipsticks. Otherwise, only the O: C ratio negatively affected on melting point. The color lipstick containing methyl methacrylate crosspolymer and stearyl dimethicone as texture enhancers, significantly provided a greater color transfer than the plain formulation. In conclusion, Thai Sacha inchi oil could be a promising antioxidant-rich oil for developing into color lipstick. To evolve the desirable lipstick, the optimum proportion of wax, fat and oil played a crucial role in both structural integrity as well as texture and spreadability.

Keywords: Color cosmetics, Lipstick, Chemical Analysis, Formulations, Statistics, Sacha inchi oil

INTRODUCTION

The global cosmetics market has been constantly expanding and diversifying due to alteration of lifestyle, rising aesthetic concerns, aging population and even climate change. Currently, the dramatic increase in trend of natural cosmetics has been widely recognized across the globe driven by environmental and health awareness contributing to rising the demand for proactive natural cosmetics especially from plant-based ingredients among customers (Amberg and Fogarassy, 2019). Besides, in consequence of the high propagation of oxidative stress and excessive production of free radicals due to global pollution, stress and excessive UV exposure, several vital functions of skin cells are considerably deteriorated leading to various aging signs, dull skin and even aged lips and loss of attractiveness (Wollina, 2013; Mukherjee *et al*., 2011; Rajendran *et al*., 2014; Tundis *et al*., 2015). The usages of antioxidants, derived from plants as ingredients in cosmetics, were extensively reported to promote potential improvements, evoke satisfactory results, and possibly increase market share (Masaki, 2010; Wollina, 2013).

The natural cosmetic trend also provokes the market demand for color lipsticks containing advantageous natural ingredients (Amberg and Fogarassy, 2019). Color lipstick has been eternally a key makeup element regarding personal grooming and aesthetic appearance of which women in all ages ordinarily consume. Typically, lipstick is composed of stiffening wax, semi-solid fat and liquid oil as structural ingredients together with an optimum mixture of color pigments, texture enhancers, and additives by which product qualities such as structural integrity, texture, pay-off and stability are modified according to consumer preference (Zibetti *et al*., 2016). Not only imparting color and vividness onto the lips but the product also provides lip's moisture due to its occlusive attribute. Moreover, antioxidants-rich natural oils within the formulation, enriched with plenty of bioactive lipophilic substances, potentially prevented skin damage from oxidation (Kasparaviciene *et al*., 2016). For instance, the oils that commonly used included rice bran oil and jojoba oil, due to their notable antioxidant capacities. In the case of castor oil, this ingredient uniquely serves as a pigment dispersing agent and solvent for stainers due to its polar nature (Knowlton and Pearce, 2013). The challenge of creating the lipstick presenting desirable characteristics is to account for the adequate proportion of the structural ingredients which essentially determine overall physical characteristics. Additionally, other additives are alternatively employed to promote aspiring attributes (Zibetti *et al*., 2016). Nowadays, an advance in technology enables cosmetic scientists to evolve the most suitable lipstick formulation with concurrently describing the significant correlations between potential factors and response parameters through the use of the statistical methodology.

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Sacha inchi (*Plukentia volubilis* L.), belongs to the plant family of Euphorbiaceae, which is a common native plant of the Amazon rainforest, mostly in Peru, South Africa (Fanali *et al*., 2011). Up to now, this plant has been extensively cultivated in Thailand for the commercial purpose (Saengsorn and Jimtaisong, 2017). Cold-pressed Sacha inchi oil derived from the seeds is widely regarded as a functional food contributing to the prevention of several diseases such as coronary heart disease, hypercholesterolemia and hypertension due to its high in α-linoleic and α-linolenic fatty acids as well as tocopherol contents (Fanali *et al*., 2011; Cisneros *et al*., 2014). According to these beneficial lipophilic substances, this oil is of great interest to be utilized as a natural antioxidant ingredient for fabricating into the color lipsticks.

Therefore, this study aimed to optimize and develop color lipstick formulation containing Sacha inchi oil utilizing the statistical method as a full factorial experimental design. The influences of structural ingredients including Sacha inchi oil, stiffening waxes and semi-solid fats on physical characteristics of lipsticks as a breaking point, hardness, and melting point were systematically elucidated. Also, antioxidant activity in terms of free radical scavenging effect and inhibition of lipid peroxidation and tocopherol content of Thai Sacha inchi oil were firstly investigated which compared to those of other antioxidant-rich oils, commonly used in lipsticks. The proper identification of the influences of each ingredient in lipsticks enabled the attainment in science of color cosmetic derived from nature.

MATERIALS AND METHODS

Materials

Carnauba wax, ozokerite wax, cetyl alcohol, petrolatum, lanolin, rice bran oil, castor oil and jojoba oil were purchased from Namsiang Co., Ltd. (Thailand). Cold-pressed Sacha inchi oil was purchased from Omega 3.6.9 and Lycopene Co., Ltd. (Kamphaeng Phet, Thailand). The color pigments used for lipstick were D & C Red No.27 (CI 77019) and titanium dioxide (CI 77891), purchased from Chanjao Longevity Co., Ltd. (Bangkok, Thailand). Trolox and D-alpha tocopherol and (+)-y-tocopherol (HPLC grade) were purchased from Sigma-Aldrich (Germany).

Evaluation of antioxidant properties of the oils

1,1-Diphenyl-2-picrylhydrazyl (DPPH) scavenging assay

Radical scavenging capacity of Thai Sacha inchi oil was evaluated through DPPH assay by the method of Poomanee *et al*. (2018) with slight modifications compared to those of antioxidant-rich oils including rice bran oil and jojoba oil. Briefly, each oil was diluted with dimethyl sulfoxide (DMSO) to give the final concentrations range of 31.25-1000mg/ml. Each oil solution was individually mixed with 167μM of DPPH methanolic solution in the ratio of 10: 100 and left in the dark for 30 min. The absorbance was then measured using a microplate reader (Spectro star Nano, BMG Labtech, Germany) at a wavelength of 520 nm. Correlation curve of percent inhibitions vs. concentrations were schemed for calculating 50% inhibitory concentration (IC_{50}). Trolox and D-alpha tocopherol served as positive controls.

Linoleic acid peroxidation assay

Inhibitory effects of the three studied oils were thus evaluated through using linoleic acid peroxidation assay according to the modified method of Poomanee *et al*. (2018). Each oil was diluted with 50% polysorbate 20 in phosphate buffer solution (PBS) pH 6.8 to give final concentrations of 62.5-1000mg/ml. The reaction mixture, composed of 1.3% w/v linoleic acid, PBS, DI water and 46.35 mM AAPH, was incubated at 45ºC for 4h. The degree of peroxidation was evaluated by the ferric-thiocyanate method. Trolox and D-alpha tocopherol served as positive controls.

Determination of tocopherol content

Tocopherol contents of the oils were elucidated by high-performance liquid chromatography (HPLC) following the method of Cisneros *et al*. (2014). HPLC Agilent HP 1200 (Hewlett Packard, Waldbronn, Germany) and Inertsil ODS-3 C_{18} particle size 5 µm, (4.6×250 mm ID) with a modified column temperature of 35ºC, were employed. Isocratic elution of absolute methanol with a flow rate of 1.0ml min^{-1} was carried out at wavelength detection of 295nm. (+)-y-tocopherol served as a-tocopherol standard. The y-tocopherol content of the oils was calculated according to the following equation;

$Y = 7.3015X; R^2 = 0.9998$

Where Y is Area Under Curve (AUC; mAU) and X is the concentration of y-tocopherol (mg/l).

Optimization of Lipstick base formulation

Following our preliminary experiment, the lipstick base was composed of waxes, fats and oils as shown in table 1, which was herein optimized through using 2-level full factorial experiment design. Three independent variables, including % Sacha inchi oil (A), Ozokerite wax-to-Carnauba wax ratio (O:C ratio; B) and % fat (C), were statistically evaluated for their main and combined effects on the response parameters as a breaking point, hardness, and melting point by analysis of variance (ANOVA).

Eight different formulations were obtained from Design-Expert 12.0.7.0 Software; Trial version (Informer Technologies, Inc., 2020) as shown in table 2, at which, variable codes and actual values of each factor were demonstrated. The mixture of lanolin: petrolatum in the ratio of 4:5 served as the fat. The amounts of Carnauba wax along with low-melting-point waxes including cetyl alcohol and white beeswax were imposed as 3.7% w/w, 3.7%w/w and 12.3%w/w, respectively in all formulations. Castor oil served as a diluent to fulfill the total amount. The statistical correlation between the independent variables and each response parameter was illustrated according to the following mathematic model;

$$Y_i = \beta_0 + \beta_A A + \beta_B B + \beta_C C + \beta_{AB} AB + \beta_{AC} AC + \beta_{BC} BC + \beta_{ABC} ABC$$

Where Y_1, Y_2, and Y_3 are response parameters defining as a breaking point, hardness and melting point, respectively, while A, B and C represent main effects of % Sacha inchi oil, O:C ratio and % Fat, respectively. Besides, AB, BC, AC and ABC represent the combined effects of the studied factors. The desirable lipstick base formulation, presenting optimum parameters, texture and pay-off, as well as containing a relatively high amount of Sacha inchi oil, was selected for further developing into color lipstick formulations.

Physical characterization of the lipstick base formulations

Breaking point

Texture analyzer (TA-XT Plus C; S table Micro Systems, United Kingdom) with a lipstick break strength rig (A/LC) was performed for determining the breaking point of the lipstick, which indicates a resistance against applying force. According to the method of Abidh *et al*. (2019) lipstick was placed horizontally in the machine and the probe was programmed to gradually drop down at a rate of 1.0mm sec^{-2} with a trigger force of 20g. The final force (g) breaking a lipstick was defined as the breaking point. The experiments were done in triplicates at 25±2ºC

Hardness

The hardness of the lipstick was measured using a penetration test by the Texture analyzer with a 2mm needle (P/2N). At the trigger force of 5g, the needle penetrated toward the center of the lipstick at a rate of 1.0 mm sec^{-2} with the target distance of 5mm. The amount of force (g), used to overcome resistance and penetrate the product, is regarded as hardness. The experiments were done in triplicates at 25±2ºC.

Melting point

The melting point of the lipstick was measured through using differential scanning calorimetry (DSC1; Mettle Toledo, USA) presenting the endothermic phase transition from solid to liquid. The aluminum pan with a sample (5.5g) was heated at a rate of 10ºC min^{-1} to reach a temperature of 120ºC. Thermo gram illustrating heat flow (J) as a function of temperature (ºC) was then obtained for detecting the melting point.

Glide evaluation

The spreadability of lipstick was expressed as a point scale of glide evaluation (Wen *et al*., 2014). The scale range of 0-10, in which 0 defines very difficult glide and 10 defines very easy glide. Each lipstick was applied onto the inner forearm in a standard forward-backward motion 3 times.

Modification of color lipstick texture and pay-off

Color mixture composed of CI 77891 and CI 77019 was incorporated at a concentration of 12.5% w/w into the optimum lipstick base. Texture and pay-off of the desired color lipstick were subsequently modified using texture enhancers including methyl methacrylate crosspolymer (PMMA) and stearyl dimethicone, which were also compared with those of a non-modified formulation. Visual appearances in terms of homogeneity and color transfer were determined. To measure color transfer, the lipstick was applied onto an accurately weighed paper with a constant force during rubbing. The paper was then weighed for calculating the difference in mass indicating the amount of product residue on the paper.

STATISTICAL ANALYSIS

All experiments were done in triplicates. The results were expressed as Mean ± standard deviation (SD.). Statistical analysis in a term of One-Way Anova with multiple comparison using Tukey was conducted for evaluating the significant difference ($P<0.05$) between each group using SPSS statistic 17.0 software (IBM Co. Ltd., USA).

RESULTS

Antioxidant capacity of Sacha inchi oil

As shown in table 3, amongst all oils, Sacha inchi oil exhibited the greatest DPPH radical scavenging capacities and the strongest inhibition on lipid peroxidation which was in correspondence with its highest y-tocopherol content. Noticeably, the amount of y-tocopherol of Sacha inchi oil, as a major tocopherol with a retention time of 12.86 min (fig. 1) was approximately 14-fold higher than that of rice bran oil.

Optimization of lipstick base formulation

Eight lipstick formulations that are not orthogonally correlated demonstrated multiple response variables indicating structural properties of the lipsticks including breaking point (Y_1), hardness (Y_2) and melting point (Y_3) (table 4). As shown in fig. 2, significant terms ($P<0.05$) were rationally selected to obtain the most adequate mathematic model of each response, which is shown a high coefficient of determination (R^2).

Breaking point

The model describing the correlation between factors and breaking point (Y_1) was the following model;

$$Y_1 = 355.55 + 68.09 B - 53.44 C - 31.31 AC + 47.56 BC - 76.69 ABC$$

Regarding this correlation model, approximately 98.89% (R^2 = 0.9889) of the response variables in a term of breaking point could be described. Even though, the combined effect of %Sacha inchi oil (A) and % Fat (C) was not a significant term as shown in fig. 2(a), this term was also chosen since it provided the highest R^2 indicating the best-fit regression model. According to the aforementioned model, the significant main effect of O: C ratio (B) positively influenced the breaking point, otherwise, % Fat (C) was negatively proportional to this response. Noticeably, the interaction terms of all factors exhibited the highest absolute effect as shown in fig. 2(a), which directly suggested the strongest influence on the breaking point. As illustrated in fig. 3, the significant interaction terms of all factors can be clearly interpreted that at the low amount of Sacha inchi oil (fig. 3(a)), the increases in either stiffening waxes or semi-solid fats offered a greater breaking strength for the lipstick structure. Meanwhile, at a high level of the oils (fig. 3(b)), it is worth noting that only stiffening waxes should be added up for increasing the breaking point since the proportion for other structural ingredients was correlatively decreased due to the increase in the liquid oil. In this case, adding-up of semi-solid fat perhaps result in loss of structural strength.

Hardness

The final model describing the influences of the factors on hardness (Y_2) was obtained as the following model, according to the factor selection in fig. 2(b);

$$Y_2 = 70.79 + 4.01\,B + 3.11\,C - 4.36\,AC - 5.33\,ABC$$

Even though, main effects of O:C ratio (B) and % Fat (C) did not significantly influence upon this response parameter (fig. 2(b)), however, the occurrence of these terms offered the best fit model, by which about 95% of the responses could be explained. The significant combined effect of % Sacha inchi oil (A) and % Fat (C) was elucidated through fig. 4(a). At high wax content (O:C ratio of 2), the high force of hardness was obtained due to the increase in % Fat corresponding to the correlation reported in the breaking point. Also, in coincidence with the breaking point, the combined effect of all factors largely influenced by hardness, which could be illustrated by fig. 4(b) and 4(c), considering at 30 %w/w and 35 %w/w of fat, respectively. fig. 4(b) demonstrated that hardness of the lipstick could be increased due to the increases in both stiffening wax and Sacha inchi oil. However, fig. 4(c) illustrated that the highest hardness could be obtained by only adding-up stiffening wax at the lowest level of liquid oil (15%).

Melting point

As shown in fig. 2(c), the obtained model suggesting the influences of the studied factors on melting point (Y_3) as the following model;

$$Y_3 = 64.39 - 0.2209\,A - 0.5627\,B - 0.3111\,AB$$

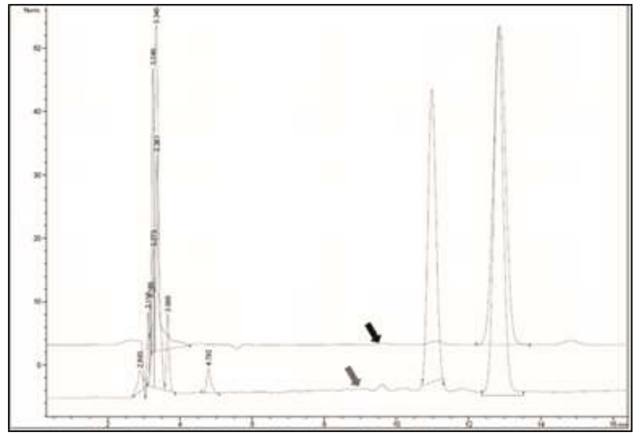

Fig. 1: HPLC chromatograms of y-tocopherol found in Sacha inchi oil (line graph with a grey arrow) compared to y-tocopherol standard (line graph with a black arrow).

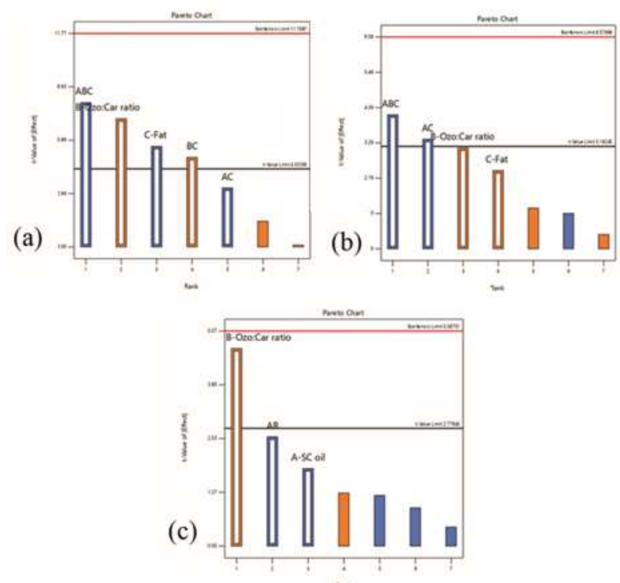

Fig. 2: Pareto charts illustrating absolute effects in a term of t-value on three dependent variables as (a) Breaking point, (b) Hardness and (c) Melting point.

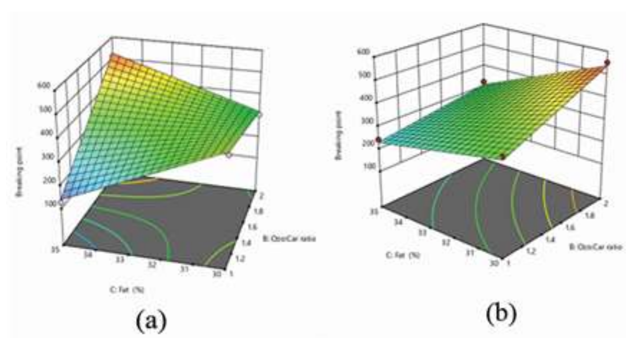

Fig. 3: Response surface plots defining the interaction effects of three studied factors (ABC) on breaking point (a) in which factor A (% Sacha inchi oil) is 15% and (b) in which factor A is 20%

Table 1: Components used for Lipstick base formulation and their functionalities

Components	Functionalities	Quantity (%w/w)
Carnauba wax	Stiffening agent	3.7
Ozokerite wax	Stiffening agent	3.7
Cetyl alcohol	Stiffening agent	3.7
White beeswax	Stiffening agent	12.3
Lanolin	Softening agent	14.8
Petrolatum	Softening agent	18.5
Sacha inchi oil	Blending agent	18.5
Castor oil	Blending agent	24.7

Table 2: Experimental matrix of independent variables obtained from the design of the experiment

Formulation	A (% Sacha inchi oil)		B (O:C ratio)		C (% fat)	
	Code	Actual value	Code	Actual value	Code	Actual value
1	-1	15	-1	1	-1	30
2	1	20	-1	1	-1	30
3	1	20	1	2	1	35
4	1	20	-1	1	1	35
5	-1	15	1	2	1	35
6	-1	15	-1	1	1	35
7	1	20	1	2	-1	30
8	-1	15	1	2	-1	30

Table 3: Antioxidant properties of Sacha inchi oil, rice bran oil, and jojoba oil, compared with standards and their γ-tocopherol contents, analyzed by HPLC

Oils	IC_{50} (mg/ml)		y-tocopherol content (mg/100g oil)
	DPPH assay	Linoleic acid peroxidation	
Sacha inchi oil	14.23 ± 0.54	12.27 ± 2.27	79.42 ± 0.69
Rice bran oil	19.11 ± 0.69	62.10 ± 1.80	5.72 ± 0.17
Jojoba oil	NA	NA	NA
Positive controls	IC_{50} (µg/ml)		
D-alpha tocopherol	296.82 ± 0.56	159.13 ± 20.59	-
Trolox	31.97 ± 1.47	151.46 ± 13.54	-

NA: not available

Table 4: Response parameters of each lipstick base formulation based on the design of the experiment

Formulation	Breaking point (g: Y_1)	Hardness (g: Y_2)	Melting point (ºC: Y_3)
1	421.18 ± 45.89	68.24 ± 0.80	63.91
2	355.73 ± 15.65	60.25 ± 5.66	63.57
3	324.29 ± 53.23	69.01 ± 0.74	64.26
4	244.50 ± 31.96	67.27 ± 4.41	64.27
5	511.23 ± 27.72	87.96 ± 5.59	65.24
6	128.42 ± 0.61	71.37 ± 6.33	63.57
7	552.04 ± 79.41	81.02 ± 3.10	64.58
8	306.98 ± 22.05	61.22 ± 5.58	65.72

Table 4 showed melting points of the obtained lipsticks in a range of 63.57-65.72ºC thereby no deformation during storage at room temperature. The main effect of %Sacha inchi oil (A) and interaction effect of A and O:C ratio (B) were not significantly correlated with the alteration of melting point, nevertheless, these terms were chosen to be in the final model because the best fit model was obtained. Besides, R^2 was 0.8878 suggesting that approximately 89% of variation can be described. Fig. 2(c) illustrated that by the increase in O:C ratio, the melting point was subsequently decreased.

From the results of glide evaluation, almost all obtained lipstick presented comparable point scales range of 5-6 except formulation 3, which demonstrated the highest scale of 7. This formulation was thus selected as an antioxidant lipstick base for further developing into color lipsticks and modifying texture and pay-off.

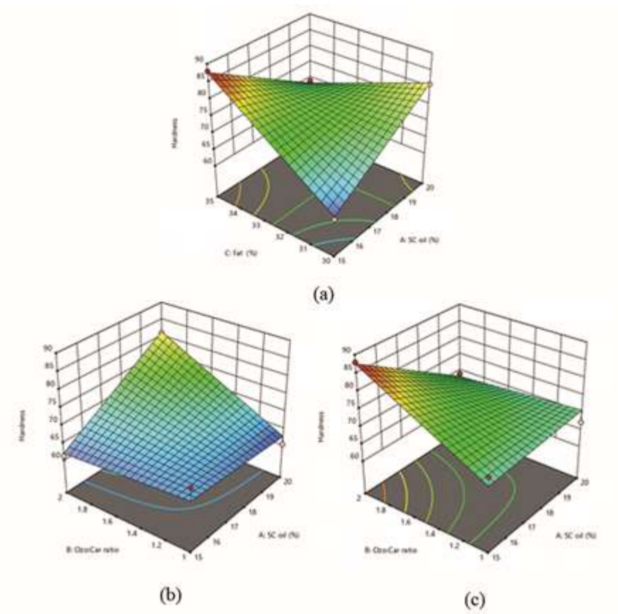

Fig. 4: Response surface plots defining the interaction effects of (a) factor A (%Sacha inchi oil) and factor C (%Fat) on hardness, in which factor B (O:C ratio) is 2, and the interaction effects of three studied factors (ABC) on hardness (b) in which factor C is 30% and (c) in which factor C is 35%

Fig. 5: Physical appearances of the obtained color lipsticks with a variation of texture enhancers (3.1) without texture enhancers, (3.2) with PMMA 4%w/w, and (3.3) with PMMA 4%w/w plus stearyl dimethicone 3%w/w

Modification of color lipstick texture and pay-off

Three color lipsticks that shown homogenous texture were obtained by varying the texture enhancers as shown in fig. 5. Color transfers of formulation 3.1, 3.2 and 3.3, expressed as weights of product residue on the paper, were 0.0014±0.0002g, 0.0018±0.0002g and 0.0023± 0.0008, respectively, indicating the amount of product occurring on the tested paper.

DISCUSSION

Antioxidant-rich natural oils including rice bran oil and jojoba oil have been widely employed as lip nourishing oils by the virtue of their notable antioxidant and moisturizing properties (Amnuaikit *et al*., 2008; Al-Obaidi *et al*., 2017). As a consequence, free radical scavenging potential and inhibition on lipid peroxidation of Thai Sacha inchi oil and the above-mentioned oils were compared. Free radical is considered as one of the initiators in the oxidative process. Besides, lipid peroxidation also plays an essential role in the actual physiological oxidation, mostly contributing to the deterioration of skin cells (Mukherjee, 2011). Therefore, natural oils exerting antioxidant capacity could be a promising ingredient for lip nourishment and preventing oxidative stress occurring in lips' skin. Moreover, lipophilic antioxidants potentially protect rancidity occurring during storage. Amongst all isomers of tocopherols, y-tocopherol is generally regarded as the most potent free radical scavenging form (Grilo *et al*., 2014). Due to the highest y-tocopherol content of Thai Sacha inchi oil, its free radical scavenging capacity and inhibitory effects on lipid peroxidation were therefore greater than those of rice bran oil and jojoba oil. Our finding also exhibited that y-tocopherol content of Thai Sacha inchi oil was approximately 8-fold higher than that of sunflower oil, an excellent source of tocopherol, reported in the study of Grilo *et al*. (2014). Also, y-tocopherol content of Thai Sacha inchi oil was significantly higher than that of Peruvian Sacha inchi oil which is regarded as the oil derived from the original area of Sacha inchi (Cisneros *et al*., 2014). Therefore, Thai Sacha inchi oil could be a promising antioxidant oil for the development as a color lipstick with an outstanding antioxidant attribute.

The optimum proportions of stiffening wax, semi-solid fat, and liquid oil eventually provided excellent structural integrity of lipstick base with desirable texture and preferable pay-off (Wen *et al*., 2014). By means of full factorial experimental design, the main and combined effects of these structural ingredients on the physical characteristics of the lipsticks were ultimately elucidated herein. According to the correlations describing lipstick strength, the structural integrity of the lipstick was mainly attributed to the combined effect of stiffening waxes, semi-solid fats, and liquid oils. Stiffening waxes played a major role in the consolidation of lipstick due to the augmentation of breaking point and hardness in all situations. On the contrary, a blending mixture of semi-solid fat and liquid oils relatively renders soft texture and ease of spreadability, which can decline breaking point and hardness into desirable levels. The breaking point is considered as the strength of lipstick withstanding bending during the application, while the hardness of lipsticks is regarded as one of the structural parameters implying product firmness, satisfactory of deposit on the lips and possibly forecasting stability (Kasparaviciene *et al*., 2016). Accordingly, these two parameters substantially determine product qualities and consumer perception. Adequate lipstick base formulations were generally reported to feature breaking point in a range of 300-400 g (Wen *et al*., 2014). Besides, the hardness of lipstick was preferably higher than 40g for preventing deformation during use and storage (Bui and El-Khouri, 2014). Our results showed whether hardness values of all obtained formulations are in a range of 60-88g suggesting the optimum hardness. Considering merely breaking point and hardness, formulation 2, 3 and 8 might be satisfactory formulations. However, the spreadability during application of each formulation, which also have a great impact on consumer preference, was necessary to be concurrently evaluated. Glide evaluation was therefore employed to identify the spreadability of the formulations in a term of glide score (Wen *et al*., 2014). It is worth noting that formulation 3, which was fabricated by the high levels of all factors provided adequate physical characteristics, the most desirable texture and spreadability during the application, as well as a high content of Sacha inchi oil (20%). Such results might be interpreted that this formulation exhibited a good strength due to high proportion of stiffening wax as well as a preferable texture due to high amount of softening materials as semi-solid wax and Sacha inchi oil. At high level of O:C wax, a proportion of ozokerite wax was increased, while the amount of carnauba wax was established as a constant level of 3.7 %w/w. Accordingly, ozokerite wax might offer a greater spreadability to the lipsticks due to its lower melting point than carnauba wax.

Melting point is one of the crucial physical parameters suggesting the temperature stability of the lipstick. From the results, O:C ratio played a significant role in the fluctuation of the melting point. Considering types of waxes used in the formulation, ozokerite wax and carnauba wax with high melting temperatures of 73ºC and 83ºC respectively were varied by increase in O:C ratio in range of 1 - 2. In consequence of higher O:C ratio, a higher proportion of ozokerite wax confer lower melting point to the finished products.

The selected formulation was developed into color lipstick which intensively modified the texture and pay-off using some texture enhancers. Formulation 3.1 representing a color lipstick without texture enhancer, significantly gave the lowest product residue on the paper. As the presence of PMMA and PMMA plus stearyl dimethicone, greater color transfers were apparently observed. PMMA is widely utilized in many healthcare fields serving as a denture base material, SPF booster for sunscreen product, and color enhancer due to its reasonable price, biocompatibility in the oval environment, as well as high stability (Gad *et al*., 2017). Our study demonstrated that PMMA apparently improves the color pay-off for the lipstick formulation due to its slippery nature. Furthermore, smoother creamy texture was uniquely observed in formulation 3.3 in the presence of stearyl dimethicone and PMMA. Stearyl Dimethicone, an alkylmethylsiloxane wax (3 %w/w), was added into the formulation by the substitution of 3 %w/w petrolatum providing an identical strength with a smoother texture. As a result, the color lipstick containing Sacha inchi oil with 4% PMMA plus 3% stearyl dimethicone was considered as an optimum color lipstick formulation with the desirable attributes.

CONCLUSIONS

In our study, color lipstick containing Sacha inchi oil was firstly invented with the optimized formulation and the modified texture. By Sacha inchi oil, the obtained lipstick was enriched with natural antioxidant constituents due to its high y-tocopherol content. Full factorial design ultimately described the significant influences of main ingredients including Sacha inchi oil, stiffening wax, and semi-solid fat on the physical characteristics of the lipsticks. The strongest influencing factors, governing the structural integrity of lipstick, was regarded as the optimum proportion between those three components. Besides, to improve the color pay-off and texture which also principally affected consumer acceptance, texture enhancers were employed. Our findings brought powerful scientific knowledge to enhance natural cosmetic technology and provided gainful information for the cosmetic science of natural lipsticks. However, clinical efficacy and consumer satisfaction would be further evaluated.

ACKNOWLEDGMENTS

The authors are thankful to the Faculty of Pharmacy, Chiang Mai University, Thailand for financial support. All facilities and laboratories were supported by Laboratories of Cosmetic Science, Faculty of Pharmacy, Chiang Mai University, Thailand.

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