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Luster measurements of lips treated with lipstick formulations

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Synopsis

In this study, digital photography in combination with image analysis was used to measure the luster of several lipstick formulations containing varying amounts and types of polymers.

A weighed amount of lipstick was applied to a mannequin's lips and the mannequin was illuminated by a uniform beam of a white light source. Digital images of the mannequin were captured with a high-resolution camera and the images were analyzed using image analysis software.

Luster analysis was performed using Stamm (L_{Stamm}) and Reich-Robbins ($L_{R\text{-}R}$) luster parameters. Statistical analysis was performed on each luster parameter (L_{Stamm} and $L_{R\text{-}R}$), peak height, and peak width. Peak heights for lipstick formulation containing 11% and 5% VP/eicosene copolymer were statistically different from those of the control. The L_{Stamm} and $L_{R\text{-}R}$ parameters for the treatment containing 11% VP/eicosene copolymer were statistically different from these of the control.

Based on the results obtained in this study, we are able to determine whether a polymer is a good pigment dispersant and contributes to visually detected shine of a lipstick upon application. The methodology presented in this paper could serve as a tool for investigators to screen their ingredients for shine in lipstick formulations.

INTRODUCTION

Lips are a predominant anatomical feature of mammals. They are made up of three to five epithelial cell layers, in contrast to the rest of the face, which is made up of 16 epithelial layers on average. Lips form a border between the exterior skin of the face and the mucous membranes in the interior of the mouth. Lips have no hair follicles, sweat glands, or sebaceous glands.

Most lipsticks are a dispersion of coloring matter in a blend of oils, fats, and waxes. They are used to impart an attractive color and appearance to lips (1). By using appropriate lipsticks, narrow lips can be made to appear wider, whereas broad sensual lips can be made to appear narrow. The color of lipstick is one of the major selling points. Color is imparted to the lips either by stain or through pigments. The depth of color and opacity of lipsticks can be varied. Lip luster (gloss, shine) is an important feature of lip appearance, and this attractive visual effect is a key consumer objective in the cosmetics market. Perception of lip luster is affected by many factors, such as the lighting of the environment, lip color, surface smoothness, and lip morphology. Luster effects are based on the interaction of light with the physicochemical properties of the substrate. They are based on the specular and diffuse reflection of light from the surface and takes into account various characteristics of the reflected light.

Hedonic evaluation of luster is commonly used to compare lipsticks with different shine profiles. Thus the need to develop quantitative methodology to enable objective luster evaluation is essential. In the field of color cosmetics, the most representative effects are those that are associated with visual effects, such as color and luster. Korichi *et al.* (2) have studied different properties and visual effects of lipstick by image analysis directly on volunteers. This method provides visual information that is similar to consumer perception and enables one to quantify, directly on volunteers, the color of lipsticks and their evaluation with time. Ryu *et al.* (3) have described wrinkle-reducing lipsticks on humans by image analysis. A lip's texture profile affects the color tone and spread phenomena of a lipstick formulation.

In this article we discuss the experimental details of luster measurements by employing image analysis for quantifying the light distribution of lips illuminated with white light. Mannequin lips were used throughout the experiment, from a mannequin head with a skin texture very similar to that of humans. The interpretation of the data is based on the shape of the light-scattering curves, calculated luster parameters, and visual examination of the digital images of the lips.

EXPERIMENTAL

MATERIALS

Ozokerite (White Ozokerite Wax SP1020) was purchased from Strahl & Pitch, West Babylon, NY. Polyethylene (Performalene Polymer) was obatined from New Phase Technologies, Sugar Land, TX. Octyldodecyl stearate (Ceraphyl ODS), diisopropyl adipate (Ceraphyl 230), octyldodecyl stearoyl stearate (Ceraphyl 847), phenethyl benzoate (X-tend 226), C12-15 alkyl lactate (Ceraphyl 41), myristyl lactate (Ceraphyl 50), phenoxyethanol (and) caprylyl glycol (Optiphen), VP/hexadecene copolymer (Ganex V-216), and VP/eicosene copolymer (Ganex V-220) were obtained from ISP, Wayne, NJ. Hydrogenated polyisobutene (Panalane L-14 E) was obtained from Lipo Chemicals, Paterson, NJ. Tocopheryl acetate was obtained from Rita, Woodstock, IL. Polybutene (Indopol H-100) was obtained from INEOS, League City, Texas. Mica, iron oxides, and titanium dioxide were obtained from BASF Corporation, Florham Park, NJ.

The mannequin (Bioskin Doll Model F-200) was purchased from Beaulax Co., Ltd, Japan. The F-200 European face model was made from polyvinyl chloride (PVC) resins and coated with a special eroded surface by a mold erosion process to create human skin texture. It simulates and feels like human skin and is specifically designed for color cosmetics and makeup applications.

METHODS

Formulations. A detailed composition of the lipstick base used in our study is displayed in Table I. Ingredients of phase I were weighed and combined together in a beaker, then

Table I
Formulation of the Lipstick Base

Phase	INCI	% W/W
I	Ozokerite wax	16.11
	Polyethylene	7.68
	Octyldodecyl stearate	19.40
	Diisopropyl adipate	3.07
	Octyldodecyl stearoyl stearate	18.40
	Phenethyl benzoate	6.14
	C12-15 alkyl lactate	16.87
	Myristyl lactate	1.54
	Hydrogenated polyisobutene	9.36
	Tocopheryl acetate	0.29
	Retinyl palmitate	0.14
II	Phenoxyethanol (and) caprylyl glycol	1.00
	Total	100.00

heated to 95°C while mixing. Phase I was mixed until it cooled down to 75°C. Phase II was weighed and added to the batch at 75°C. Mixing continued until the batch was homogeneous. The formulations were prepared by mixing the appropriate amounts of base with pigments and polymers according to Table II. Phases I, II, and III were added to the base separately. Each phase was mixed for about 10 minutes at about 80°C. The formula was poured into molds at 80°C. The molds were then placed in a refrigerator for 15 minutes. The sticks were then placed in cases.

Lipstick application. A weighed amount of each lipstick formulation, including the control and formulations A, B, C, D, and E, was applied on the mannequin's lips. The applied amount of lipstick was varied from the 0.01 g to 0.02 g. All lipstick formulations were applied four times in order to ensure experimental reproducibility, and photographs were taken with each application.

Digital photography. The experimental setup for luster measurements of lips was performed on a Beseler CS-14 copystand as shown in Figure 1. The mannequin's head was

Table II
Compositions of Tested Lipstick Formulations

Phase	INCI	Formulations (% W/W)						
		Control	A	B	C	D	E	F
I	Lipstick base	75.0	64.0	64.0	64.0	70.0	70.0	70.0
	VP/hexadecene copolymer		11.0		7.0			5.0
	VP/eicosene copolymer			11.0	4.0		5.0	
	Polybutene					5.0		
II	D&C Red No.7 in isocetyl stearoyl stearate	2.7	2.7	2.7	2.7	2.7	2.7	2.7
III	Mica (and) iron oxides (and) titanium dioxide	22.3	22.3	22.3	22.3	22.3	22.3	22.3
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

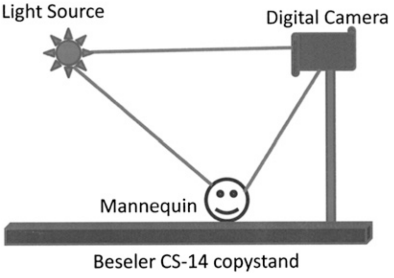

Figure 1. Diagram showing the positioning of the mannequin in relation to the light source and the digital camera.

rested on a hard stand at a certain angle. A white light source (14 W) was placed at a distance of 24 inches from the mannequin's head. The digital camera was positioned at a distance of 12 inches, providing an angle of approximately 30° relative to the central axis of the mannequin's head. The digital camera was mounted on a stationary mount and connected to a computer. A color code chart was placed at the base of the mannequin in order to calculate the white balance and provide a scale. A Cannon EOS 20D digital camera with a resolution of 8.2 MP, and equipped with an EFS 17-55 mm (f/3.5-7.1) lens, was employed as the image collection device for all studies presented in this article.

Digital images were captured as raw images files (CR2) remotely by a computer. The white balance was adjusted to the corresponding lamp color temperature, 3800°K (Camera Raw, Photoshop 10 – Adobe Systems Inc). Image analysis was carried out using ImageJ version 1.42q software (NIH), which enabled us to obtain light intensity (luminance) distributions along the lower lip of the mannequin. A 950 × 550 pixel image of the lip area of the mannequin was cropped from the original image; the shine band of the lower lip was further cropped from this image and analyzed for luster. The image was rotated 90° to the right, and converted to 8-bit, and a profile was generated measuring the light intensity across the distribution gradient. The analysis was applied to all images of all treatments.

Luster calculations. The occurrence of reflection is the result of the interaction of light with a substrate, based on its material properties. The interaction of light with objects also creates scattering, refraction, diffraction, interference, and adsorption. The most important part of luster comes from the specular and diffuse reflection.

Luster measurements of hair have been the subject of research for the past 35 years, and are unlike the luster measurements of lips, which have been mostly qualitative (4). A goniophotometer was employed by Stamm and coworkers in 1977 (5) to record the light distribution curves necessary to calculate the luster parameters of hair. Further work with goniophotometry was completed by Reich and Robbins (6), who were able to show a correlation between this quantitative technique and qualitative consumer studies. McMullen and Jachowicz (7) employed image analysis to calculate the luster parameters of hair by utilizing high-resolution digital photography in conjunction with the data analysis procedures set forth by the goniophotometric technique. The equations used to calculate luster were adopted from Stamm *et al*. (5) and Reich and Robbins (6).

Stamm *et al.* (5) proposed a luster parameter based on the specular and diffuse reflectance area under the curve:

$$L_{Stamm} = \frac{S - D}{S} \tag{1}$$

Reich and Robbins (6) offered a slightly different relationship to define luster:

$$L_{R-R} = \frac{S}{D \times W_{1/2}} \tag{2}$$

where S represents the area underneath the specular curve, D represents the area underneath the diffuse curve, $W_{1/2}$ represents the width of the specular peak at half of its maximum intensity, and L represents luster or shine. A schematic describing the specular and diffuse reflectance is presented in Figure 2.

Statistical analysis. Normality of the data was checked using the Wilk-Shapiro test, and equality of variance was checked using Bartlet's test. When normality failed, a Kruskall-Wallis non-parametric evaluation was performed along with a Dunnett's test to compare multiple treatments to a control. When equality of variance failed, a Dunn's test was performed to compare multiple treatments to a control. Statistical analysis was performed using Sigma Plot 11 software (Systat Software, Inc., San Jose, CA).

RESULTS

Figure 3 provides digital photographs of treated lips with the formulations tested, the cropped photographs with the shine bands, and the converted 8-bit gray scale images. It is very noticeable from the images that differences among treatments are more noticeable in the cropped image than in the full-lip images; however, gray scale images accentuate the differences the most. Based on visual observations, it can be seen that all treatments had more shine than the control, with treatment D (5% polybutene) being the least different and treatments C (7% VP/hexadecene copolymer and 4% VP/eicosene copolymer),

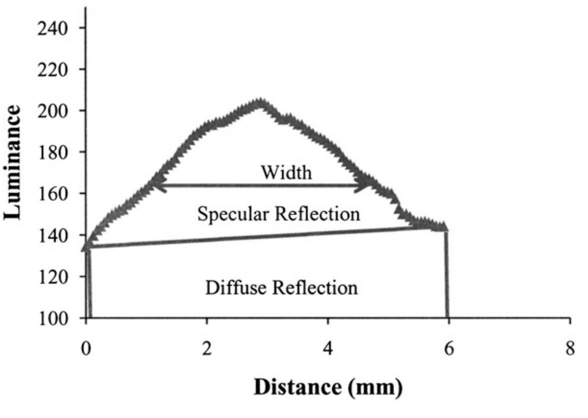

Figure 2. Schematic of the calculation of the luster parameter, which shows the difference between specular and diffuse reflectance.

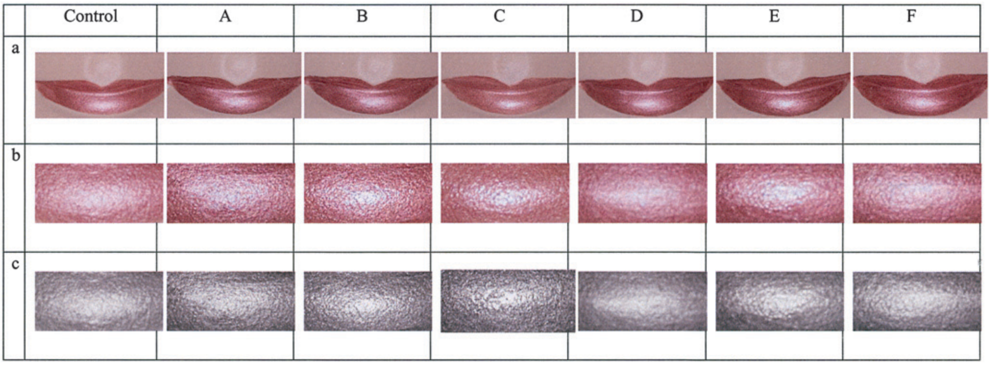

Figure 3. (a) Cropped photographs of mannequin lips treated with lipstick formulations. (b) Images of shine band cropped from above photographs. (c) Images shown were converted into 8-bit gray scale. Exposure values: f/7.1, 1/80s, 800 ISO.

B (11% VP/eicosene copolymer), and E (5% VP/eicosene copolymer) providing greater luster than the others.

Image analysis was performed on the shine bands obtained from various treatments, and the results are plotted in Figure 4. Reflectance curves generated in Figure 4 depict the differences seen visually on the images. Treatment B (11% VP/eicosene copolymer) has the highest peak; in other words, it has the greatest shine. Treatments C (7% VP/hexadecene copolymer and 4% VP/eicosene copolymer) and E (5% VP/eicosene copolymer) are slightly lower, and treatment D (5% polybutene) came closest to the control. The results

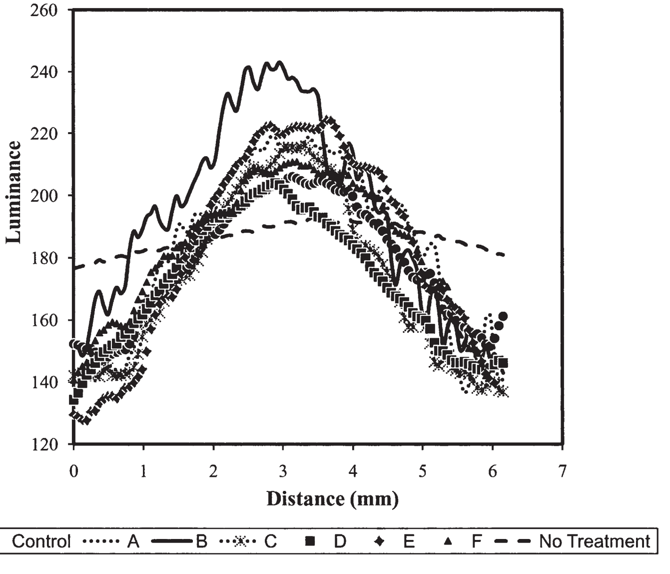

Figure 4. Light intensity as a function of distance perpendicular to the lower lips for various lipstick formulations.

seem to be in agreement with the visual differences depicted among treatments, but a more rigorous analysis was needed.

Luster parameters for the various formulations evaluated were calculated using equations 1 and 2, and the results are displayed in Table III. The results shown represent average and standard deviation values obtained from four separate measurements for each treatment. The results for the peak height were 197.54, 242.25, 214.07, 217.01, 197.89, 230.63, and 213.96 for the control and formulations A, B, C, D, E, and F, respectively. The two treatments that had the highest peaks and were statistically different from the control were treatments B (11% VP/eicosene copolymer) and E (5% VP/eicosene copolymer). The rest of the treatments, although visually different, were not statistically different from the control. Both luster parameters were calculated: L_{Stamm} and $L_{R\text{-}R}$. The values for L_{Stamm} were 0.18, 0.27, 0.23, 0.21, 0.18, 0.25, and 0.24 for the control and formulations A, B, C, D, E, and F, respectively. The values for $L_{R\text{-}R}$ were 0.36, 0.45, 0.37, 0.43, 0.38, 0.39, and 0.36 for the control and formulations A, B, C, D, E, and F, respectively. The only treatment that was statistically different from the control in both luster parameters was treatment B (11% VP/eicosene copolymer).

DISCUSSION

It appears from the results obtained thus far that the addition of VP/eicosene copolymer to lipstick formulations increases their shine. The incremental increase in shine is concentration-dependent, as the lipstick containing 11% has more shine than the one containing 5% only. The addition of polybutene to lipstick has a very small contribution to shine compared to the control. On the other hand, the addition of VP/hexadecene copolymer contributed to the overall shine but was not as effective as the addition of VP/eicosene copolymer.

The abilities of the two polymers, VP/hexadecene and VP/eicosene, to impart shine in lipstick formulations in two different capacities led us to pay more attention to their chemical structures. They are both derived from VP and long-chain alpha olefins; however, they do not have the same alkyl chain length, degree of alkylation, or molecular

Table III
Luster Parameters of Evaluated Lipstick Formulations

	Control		A		B		C		D		E		F	
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
Specular	1038.70	60.34	1081.78	14.86	1153.39*	48.32	1074.52	14.65	1028.80	31.03	1131.93*	23.95	1102.88	8.15
Diffuse	856.44	101.88	835.55	19.23	844.75	37.17	852.62	14.50	846.58	20.07	851.09	46.38	841.94	4.09
Peak	197.54	9.83	214.07	3.67	242.25*	2.19	217.01	1.41	197.89	7.02	230.63*	8.11	213.96	5.44
Max width	3.37	0.45	3.52	0.16	3.05	0.24	2.92	0.25	3.23	0.31	3.29	0.41	3.69	0.11
L_{Stamm}	0.18	0.05	0.23	0.02	0.27*	0.01	0.21	0.01	0.18	0.02	0.25	0.03	0.24	0.01
$L_{R\text{-}R}$	0.36	0.03	0.37	0.02	0.45*	0.03	0.43	0.03	0.38	0.04	0.39	0.01	0.36	0.01

*Treatments statistically significant from the control at $p < 0.05$.

weight. These polymers are often used as pigment dispersants and film formers. If the addition of a polymer helps create a better pigment dispersion, the formulation will have better shine since shine is more visible in darker shades than in lighter ones. Our insight to identify their mode of action led us to calculate RGB values for all formulations used, to evaluate if pigment dispersion was a factor. These data are displayed in Table IV and plotted in Figure 5. RGB values of lips treated with different lipstick formulations were obtained by image histogram analysis. Averages and standard deviations of the RGB values displayed were obtained from four separate treatments for each formulation. Total RGB values for the control and formulations A, B, C, D and E were 275.0, 221.6, 209.1, 196.1, 213.2, and 222.4, respectively. Only two formulations were statistically different from the control: formulations B (11% VP/eicosene) and C (7% VP/hexadecene copolymer and 4% VP/eicosene copolymer).

CONCLUSIONS

Based on the results obtained in this study, we can conclude that both of the tested VP-containing polymers are good pigment dispersants and will contribute to visually detected shine from lipsticks. The method presented in this paper could help researchers screen formulations for their optical properties.

Table IV
RGB Values of Evaluated Lipstick Formulations

	Control		A		B		C		D		E		F	
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
Red	136.4	3.0	117.9	6.20	112.2*	2.3	106.89*	0.7	114.7	3.6	120.9	1.9	119.0	2.2
Green	61.2	3.5	45.7	5.54	42.2	3.2	39.09*	0.4	41.1*	3.4	47.8	2.2	44.6	1.0
Blue	77.3	1.9	58.1*	5.49	54.8*	2.4	50.15*	1.2	57.1*	3.4	62.3	0.7	58.80*	1.4
Total	275.0	8.3	221.6	17.07	209.1*	7.8	196.13*	2.1	213.2	10.3	231.0	4.6	222.4	4.6

*Treatments statistically significant from the control at $p < 0.05$.

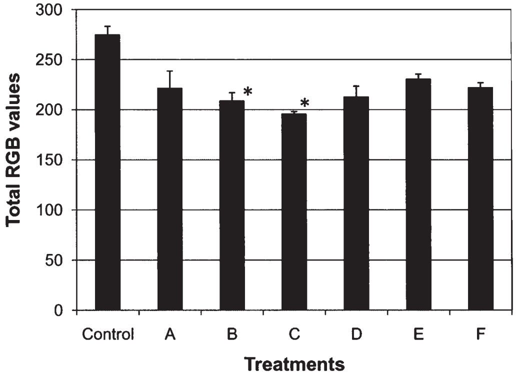

Figure 5. A comparison of different treatments based on the total RGB values of lipsticks. *Treatments statistically significant from the control at $p < 0.05$.

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