Film Coating Process Considerations for the Application of High Productivity, High Solids Concentration Film Coating Formulations

PURPOSE

In recent years, low viscosity, aqueous film coating formulations have been developed for application at higher solids concentrations than previously achievable. A substantial benefit of these low viscosity formulations is their ability to be applied at ≥ 25% solids concentration in an aqueous dispersion, thus reducing overall coating process time.[1] Other benefits resulting from low viscosity film coating systems may include efficient droplet atomization, smoother coated tablet surfaces and less process related issues such as nozzle blockages.

Traditionally, aqueous film coating is conducted in either fully or partially perforated, batch-type coating pans. As the solids concentration of the coating material increases, the time to deliver the desired quantity of coating decreases. Consequently, the overall time that the tablets will have to be uniformly presented to the spray zone will be reduced. Process parameters such as pan speed rotation and spray rate must be optimized to minimize variability in coating uniformity. The purpose of this study was to use a Design of Experiments (DOE) approach to examine the effect of solids concentration on color uniformity and coating weight variation (CWV) in a batch coating process.

METHODS

Twenty film coating trials were conducted using Opadry® II, high performance film coating system (PVA-based, Colorcon, Inc.). The coating was applied to placebo tablets, 300 mg, in a 24” fully perforated pan (Labcoat II, O’Hara Technologies) equipped with two spray guns (VAU, Spraying Systems Inc.). The process variables and ranges were: solids concentration (15% - 30%), pan speed (8-14 rpm) and spray rate (30-70 g/min). The process constants were target weight gain (3.0%), pan load (14 kg), process airflow (265 cfm / 450 m3/hr.), and tablet bed temperature (44°C). The inlet temperature was varied as necessary to maintain the target bed temperature. The individual trial parameters are listed in Table 1.

Tablet samples were withdrawn from each trial at 1.0, 2.0 and 3.0% theoretical weight gain (WG) and tested for color development and uniformity using a Milton Roy Colormate (Diano Color Products) employing the Commission Internationale de l’Eclairage (CIE) L* a* b* system. The total color difference (ΔE) from the target reference color was determined by calculating the distance between two points in the color space using the following equation:

$$\Delta E^* = [(L^*1 - L^*2)^2 + (a^*1 - a^*2)^2 + (b^*1 - b^*2)^2]1/2$$

The standard deviation (SD) of color difference between calculated ΔE values of the individual tablets from each set of samples were compared as a measure of coating uniformity. A ΔE value of < 2 indicates no visual difference in color from the target reference color. This spectrophotometric method for assessing the color development and uniformity of coated tablets in relation to coating process parameters is well documented.[2]

Coating weight variation (CWV) was assessed via 100 individually numbered, dried and pre-weighed tablets that were added to each batch then collected, dried and re-weighed after the application of the yellow coating. The light yellow color allowed the numbering on the tablets to still be visible. The samples were also inspected for defects and assessed via optical scanning profilometry (ST400 3D profilometer, Nanovea) for surface roughness.

Table 1. Experimental Coating Process Conditions

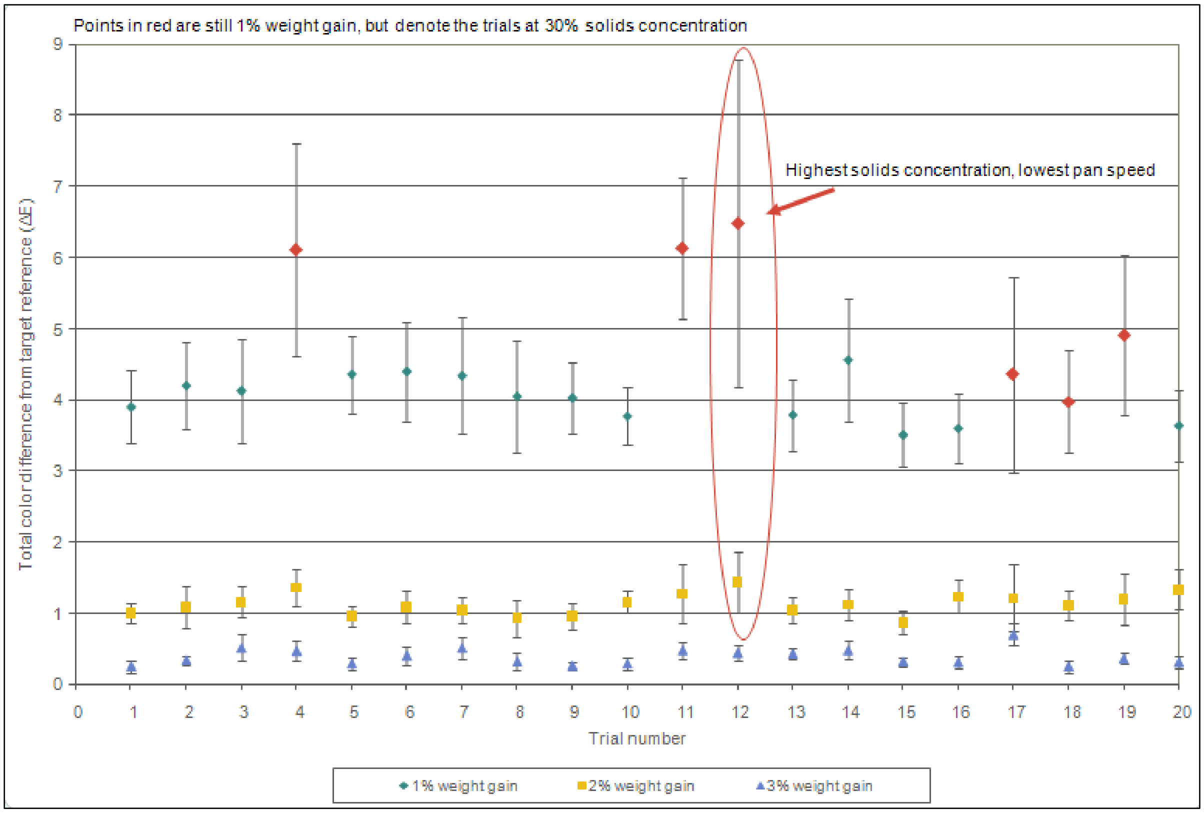
Trial Number	Process Variables				
	Pan Speed (rpm)	**Spray Rate (grams / min.)**	**Solids Concentration (%)**	**Coating Suspension Applied (g)**	**Total Coating Process Time (min)**
1	14.0	30	22.50	1866.7	62.2
2	9.5	60	18.75	2240.0	37.3
3	8.0	70	15.00	2800.0	40.0
4	11.0	30	30.00	1400.0	46.7
5	12.5	40	26.25	1600.0	40.0
6	11.0	50	22.50	1866.7	37.3
7	8.0	70	15.00	2800.0	40.0
8	9.5	60	26.25	1600.0	26.7
9	8.0	30	22.50	1866.7	62.2
10	12.5	60	18.75	2240.0	37.3
11	14.0	70	30.00	1400.0	20.0
12	8.0	50	30.00	1400.0	28.0
13	14.0	70	15.00	2800.0	40.0
14	11.0	50	22.50	1866.7	37.3
15	14.0	30	15.00	2800.0	93.3
16	12.5	60	26.25	1600.0	26.7
17	8.0	70	30.00	1400.0	20.0
18	11.0	30	30.00	1400.0	46.7
19	14.0	50	30.00	1400.0	28.0
20	8.0	30	15.00	2800.0	93.3

RESULTS

Color Development and Uniformity

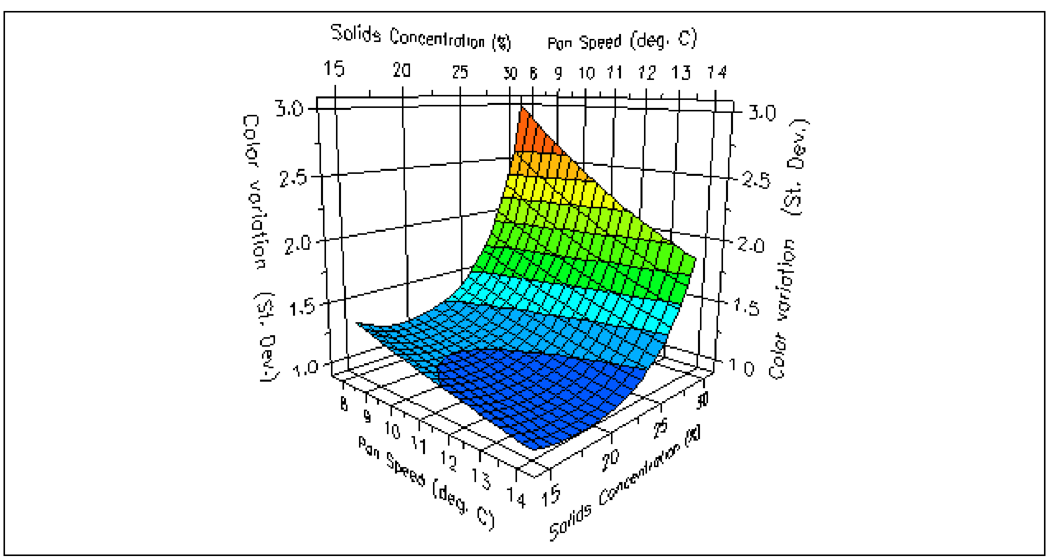
At the final 3% WG, all trials attained the target color with <1 ΔE (<0.4 SD). Excellent color uniformity was achieved irrespective of process conditions. Samples taken at 2% WG exhibited higher color variation, but were all still within the <2 ΔE limit of visual detection. Significant variation in color development and uniformity as seen with the samples taken at the very low 1% WG. Trials conducted at 30% solids concentration and low pan speeds exhibited the highest variations in color uniformity (Figure 1).

Figure 1. Color Development and Uniformity for All Trials



Statistical analysis of the color data for samples taken at ≥ 2% WG showed no significant impact of the process variables, within the ranges studied, on color development and uniformity. This indicates that in terms of achieving the desired color, application of greater than 2% WG of coating masked the influence of the studied variables. The effect of the process variables was, however, statistically significant for the samples taken at 1% WG of coating. The primary effectors for color variation for the samples taken at 1%WG were pan speed and solids concentration (Figure 2).

Figure 2. Effect of Pan Speed and Solids Concentration on Coating Color Variation at 1.0% WG

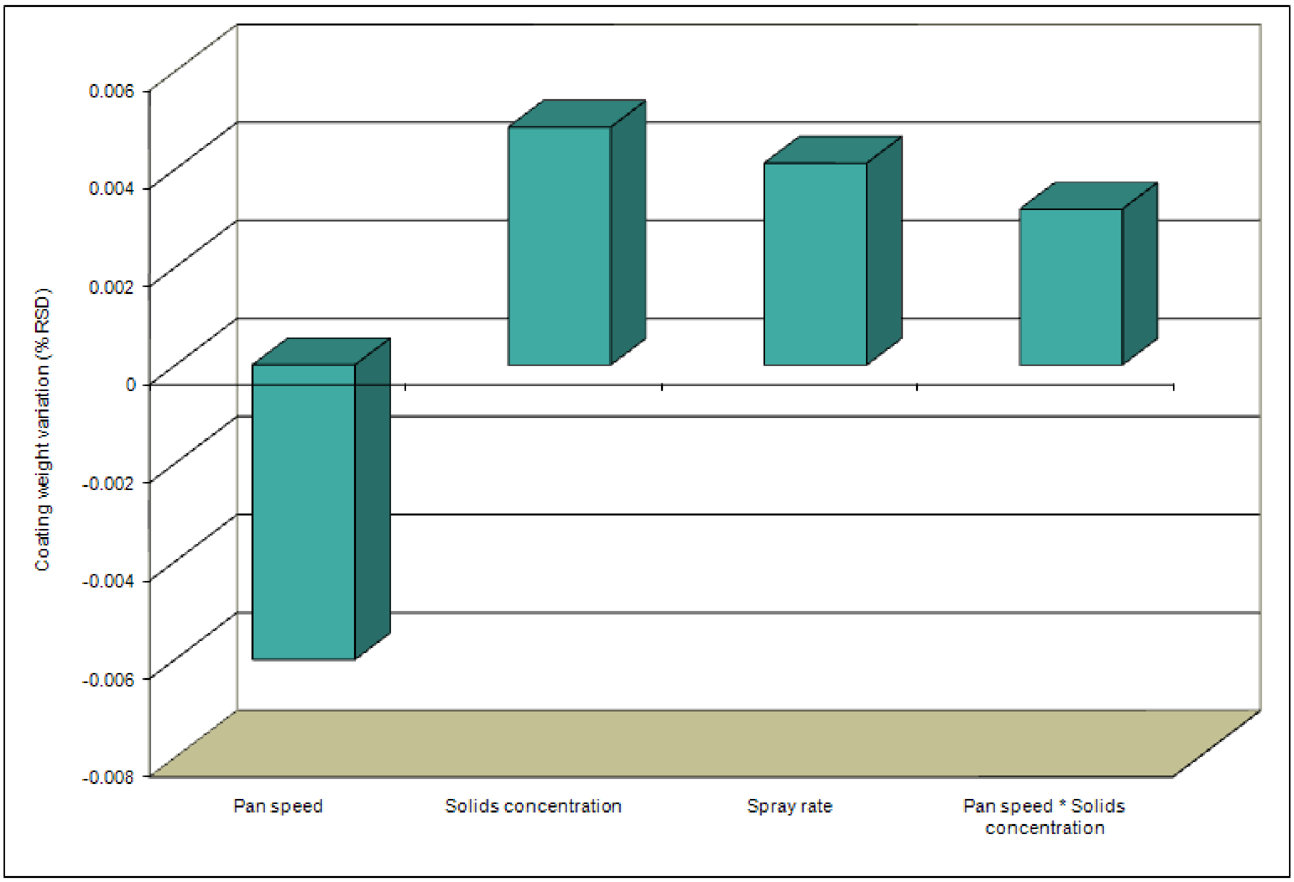


At low coating levels, as the solids concentration of the coating dispersion increased, tablet color uniformity decreased. This effect is driven primarily by coating time. Batches with the highest solids concentrations and highest spray rates resulted in very short process times (as low as 20 minutes to apply a theoretical 3% WG) and reduced opportunity for the tablets to uniformly present themselves to the spray zone. To some extent, this effect can be mitigated by increasing the pan speed, which allowed for more frequent tablet presentation to the spray zone and improved color uniformity.

Coating Weight Variation

At 3% WG, CWV ranged from 7.2% relative standard deviation (RSD) to14.3% RSD. Pan speed and solids concentration were the greatest effectors of CWV with spray rate also having a significant effect (Figure 3).

Figure 3.Coating Weight Variation Variable Effect Ranking



Increases in pan speed resulted in lower CWV while increases in solids concentration and spray rate resulted in increased CWV. The analysis of weight uniformity data for the 20 trials supported the color uniformity results. The combination of higher spray rate and higher solids concentration resulted in lower coating uniformity; however, these effects can be limited if combined with higher pan speeds. Response surface graphs were generated to examine the interactive effects of pan speeds and spray rates on coating weight variation at increasing solids concentration at 3.0% WG (Figures 4-6).

Figure 4.Effect of Pan Speed and Spray Rate on CWV at 15.0% Solids Concentration (3% WG)

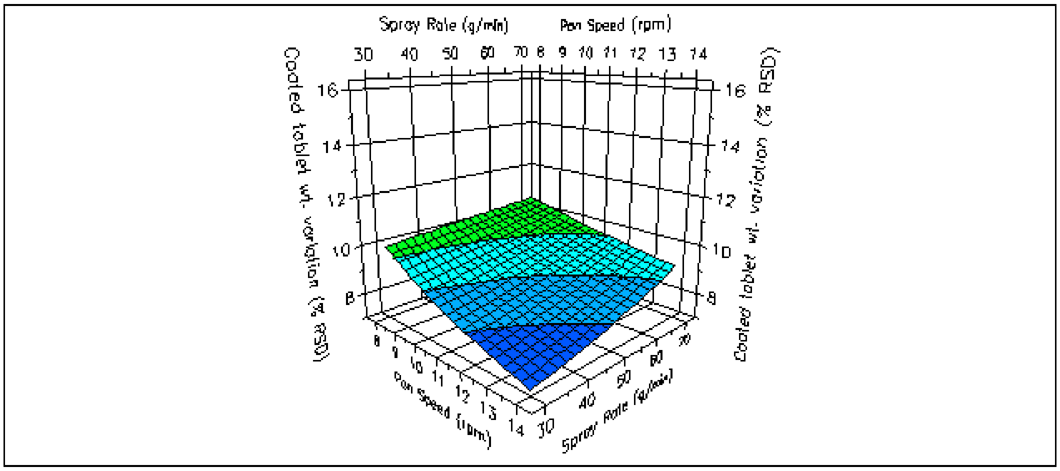


Figure 5.Effect of Pan Speed and Spray Rate on CWV at 22.5% Solids Concentration (3.0% WG)

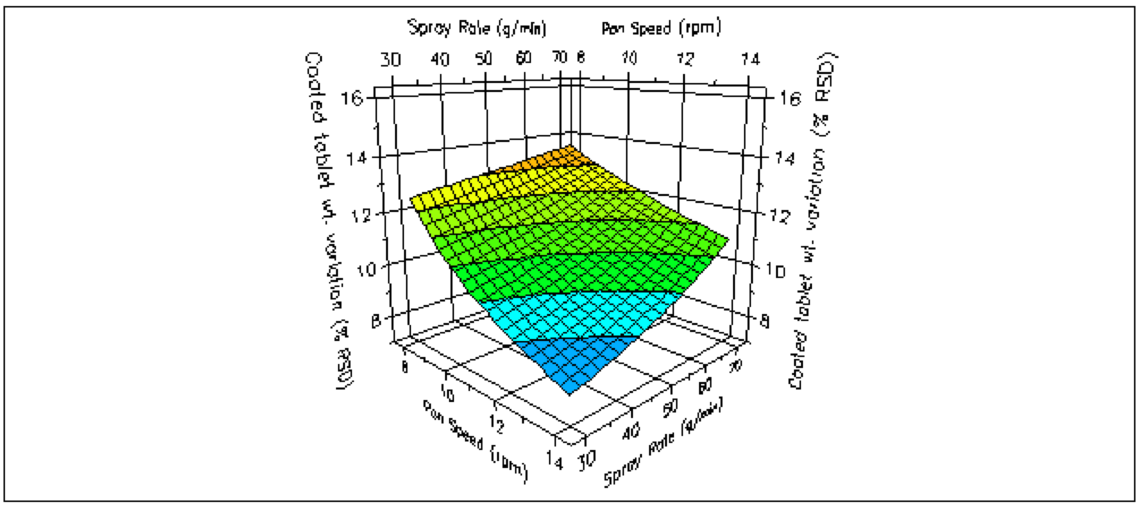
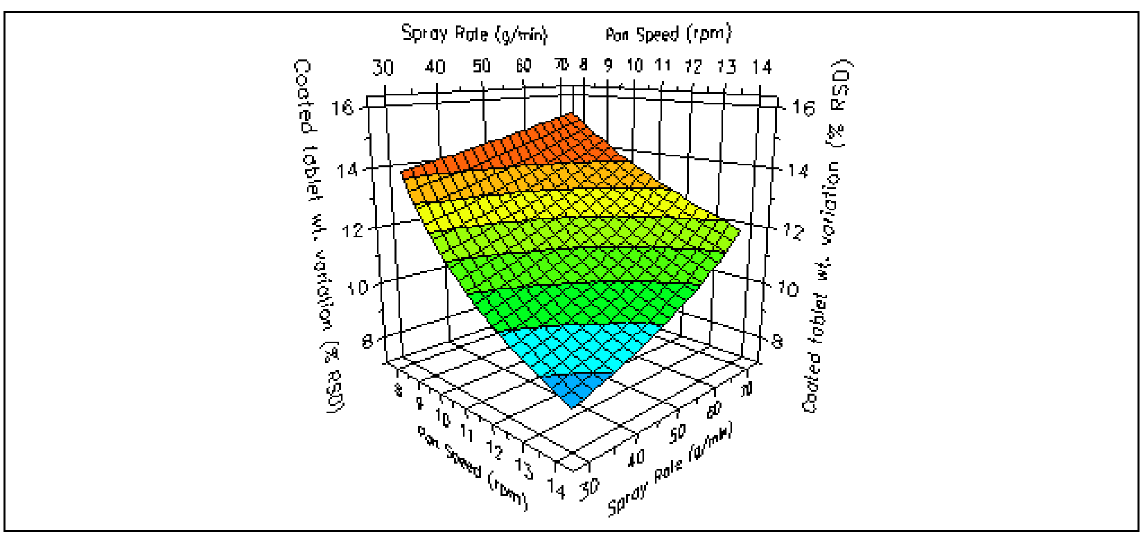


Figure 6.Effect of Pan Speed and Spray Rate on CWV at 30.0% Solids Concentration (3.0% WG)



A combination of the lowest spray rates, lowest coating solids concentration and highest pan speeds were shown to provide the best coating weight uniformity.

Coated Tablet Appearance

The tablets from all of the trials were free of visible defects irrespective of the process conditions used. Trials with lower CWV produced smoother tablet surfaces. The entire range of surface roughness averages across the trials was from 2.6 to 7.3 microns. Data analysis for surface roughness was consistent with the weight uniformity data with higher spray rates and solids concentrations resulting in higher surface roughness. Increasing pan speeds resulted in smoother tablet surfaces (Figures 7-8).

Figure 7.Effect of Pan Speed and Solids Concentration on Surface Roughness at 30 g/min Spray Rate (3.0% WG)

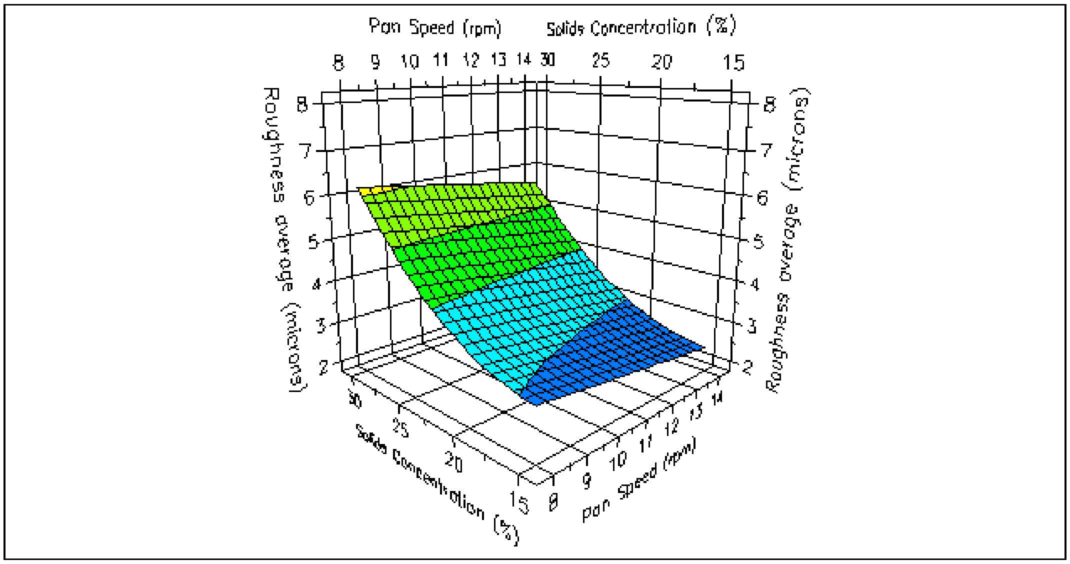
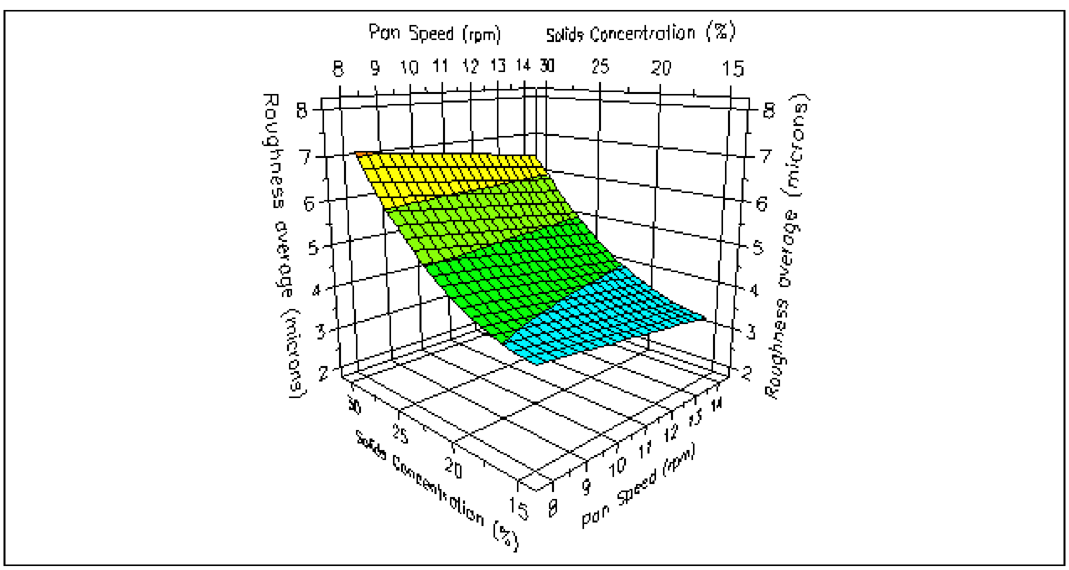


Figure 8.Effect of Pan Speed and Solids Concentration on Surface Roughness at 70 g/min Spray Rate (3.0% WG)



CONCLUSIONS

High solids aqueous coating dispersions can be successfully applied to achieve color uniformity with a significant reduction in coating time compared to coating dispersions applied at lower solids concentrations. It is important to consider that color uniformity can be achieved in significantly less time than actual coating weight uniformity. Thus, the overall objective of the coating, aesthetic vs. functional, should be considered when optimizing coating process parameters including dispersion solids concentration.

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2. Porter, SC, (1988) Opportunities for Cost Containment in Aqueous Film Coating. Pharmaceutical Technology 12 (Sept): 62-75.

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