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COMMUNICATIONS

A COMPARISON OF FREE-FLOWING, SEGREGATING AND NON-FREE-FLOWING, COHESIVE MIXING SYSTEMS IN ASSESSING THE PERFORMANCE OF A MODIFIED V-SHAPED SOLIDS MIXER

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SUMMARY

The performance of a modified V-shaped solids mixer, i.e., uneven leg or offset angle, has been reassessed by using a binary cohesive mixture, made up of 1% sodium salicylate and 99% microcrystalline cellulose, as the mixing system. The performance of the mixer was defined in terms of relative standard deviation from the measured mean. The results generated from the present study were compared with the previously published data generated by using a free-flow mixing system. It appears in the present study that the free-flowing, segregating materials may be used as a mixing model to predict the trend of the performance of a modified V-shaped blender for the non-free-flowing, cohesive materials. However, in the equilibrium state, the non-free-flowing, cohesive mixture has much better quality of the mix than that of the free-flowing, segregating system in terms of the scale and intensity of segregation.

INTRODUCTION

The flow property of powder is evidently an important characteristic and leads to a general division of powder mixtures into two categories: free flowing, segregating materials and non-free-flowing, cohesive materials. It is quite common to investigate the fundamental mix/segregation mechanisms, the performance of solids mixers, and the scale-up of the blending process using segregating materials (1-5). This approach

TABLE I.
Properties of Sodium Salicylate and Microcrystalline Cellulose

	sodium salicylate	microcrystalline cellulose
Particle size distribution[a]		
10 percentile size (um)	8.27	44.14
50 percentile size (um)	22.29	141.31
90 percentile size (um)	45.21	245.87
Bulk density (g/cc)	0.28	0.33
Tapped density (g/cc)[b]	0.43	0.44
Moisture content (%)[c]	0.21	3.75
Shape	Fig. 1	Fig. 2

a Malvern laser particle size analyzer
b tapped to constant volume
c Computrac moisture balance; temperature setting at 105 °C for 10 min.

attempts to simplify the mixing system to minimize the difficulties of the mixing study. The extrapolation of the results generated from the studies using free flowing, segregating materials to the non-free-flowing, cohesive systems may be questionable as significant differences exist between these two systems. No study has been reported, however, to probe the effects on mixing due to the differences between two mixing systems.

Recently, Chang et. al. used free flowing, segregating materials (binary mixture of potassium chloride crystals and non-pareil seeds) to demonstrate that improvement in mixedness can be obtained by leg reduction and/or offset angle of a V-shaped blender (1). The purposes of the present study were: (a) to investigate the effect of leg-reduction and offset angle of a V-shaped blender on mixing efficiency using non-free-flowing,

FIGURE 1
Photomicrograph of jet milled sodium salicylate

cohesive materials; and (b) to compare the results generated from using two mixing systems.

MATERIALS AND METHODS

A binary non-free-flowing mixture of microcrystalline cellulose (Avicel PH 102, FMC Corp., Philadelphia, PA) and jet-milled sodium salicylate (Sigma Chemical Co., St. Louis, MO) was chosen as the mixing system. The properties and photomicrographs of the two ingredients are given in the Table 1 and Figures 1 and 2.

A twin-shell solid-solids blender frame (Patterson Kelley Co., East Stroudsburg, PA, Model SB-8) and a half-quart stainless-steel shell (Patterson Kelley Co., Model YS-1/2) in conjunction with a specially designed yoke and a leg reduction device as described previously were used in the present study (1). The rotational speed of the mixer was fixed at 30 rpm for all tests. Microcrystalline cellulose (150 g) was loaded into the mixer as a bottom layer and sodium salicylate (1.5 g) as the top layer. The

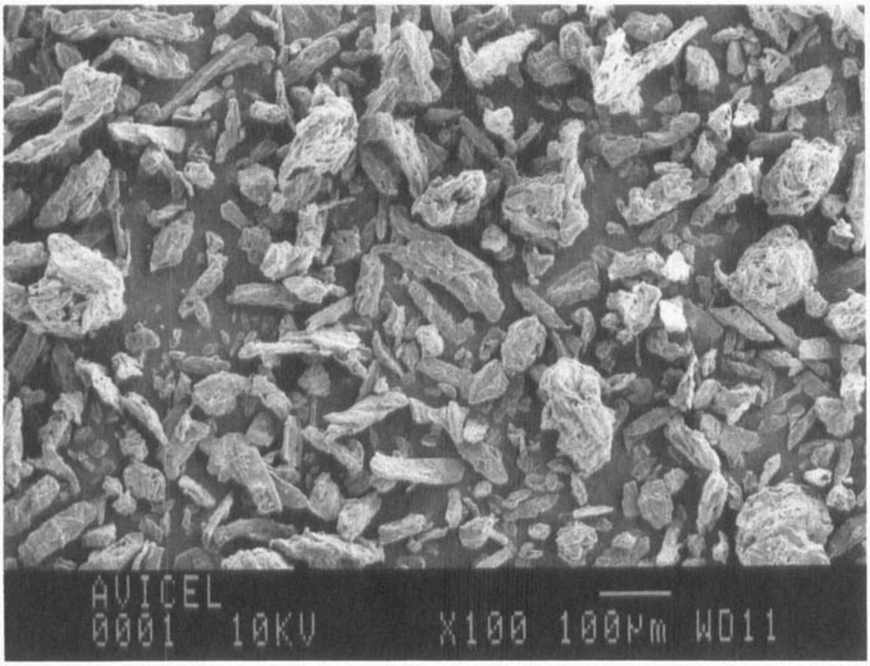

FIGURE 2
Photomicrograph of microcrystalline cellulose (Avicel PH 102)

variables investigated in the present study included leg reduction(0, 10, 20, 40, and 60%) and offset angle (0, 15, 30, 45, 60, 75, and 90^0). The mixer with preset offset angle or leg reduction was set in motion for five minutes and the contents discharged by hand through the discharge port. Twenty samples of this discharge were randomly taken by using a dosator (a #0 capsule dosing unit of Zanasi encapsulation machine). The mean weight of the sample taken was 225 mg with a range of 200-250 mg. Accurately weighed sample was transferred to a 100 ml volumetric flask. Distilled water was added to the volume to dissolve sodium salicylate. A sample of the clear supernatant was transferred to a clean tube and assayed spectrophotometrically at 298 nm for sodium salicylate content using a Diode Array Spectrophotometer (Hewlett Packard, model 8451A) with auto sampler (Hewlett Packard, model 89072A). The quality of mixing achieved was estimated by the relative standard deviation of the assay results of the samples withdrawn from the batch. All experiments were conducted in tripricate.

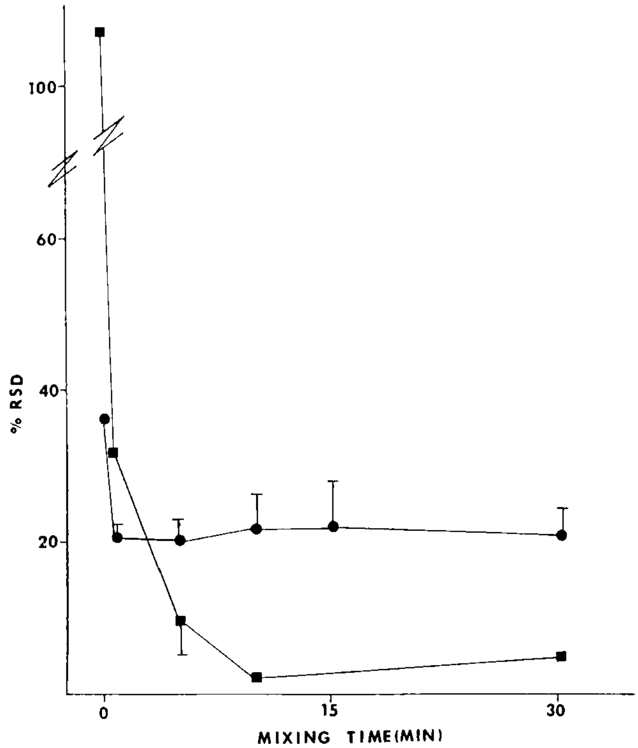

FIGURE 3
The variation of mixture quality with various mixing times for the free flowing, segregating and non-free-flowing, cohesive mixing systems (RSD, relative standard deviation from the measured mean).
● the free-flowing, segregating system
■ the non-free-flowing, cohesive system

RESULTS AND DISCUSSION

Figure 3 shows a plot of the relative standard deviation from the measured mean, for both the free-flowing, segregating mixing system and the non-free-flowing, cohesive system, against the mixing times. Compared to the free-flowing mixing system, blending of the cohesive mixture requires more energy to generate the interparticulate motion and is a relatively slow process to reach the equilibrium state. However, in the equilibrium state, cohesive mixture has much better quality of mix than that of the free-flowing system in terms of the scale and intensity of segregation. Free-flowing materials are commonly

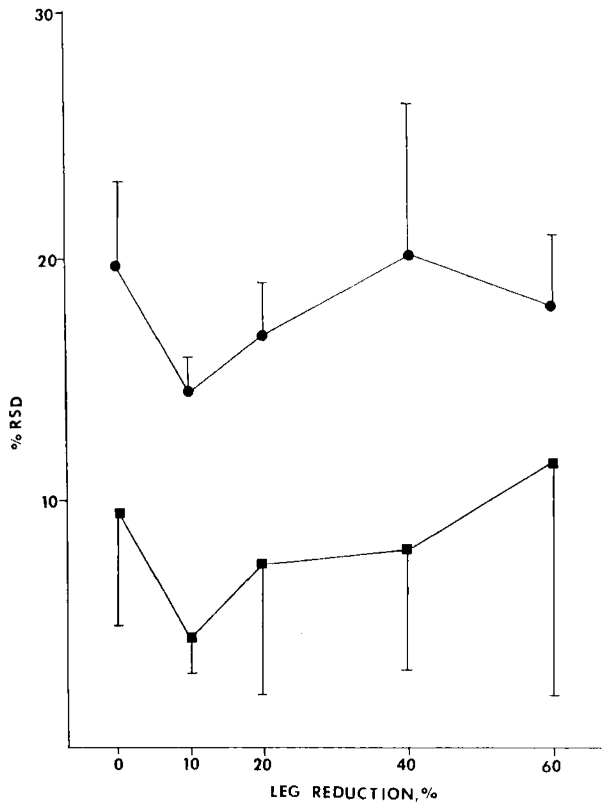

FIGURE 4
Effect of leg-reduction on the mixedness of the free flowing, segregating and non-free-flowing, cohesive mixing systems for five min. mixing runs (RSD, relative standard deviation from the measured mean).

● the free flowing, segregating system
■ the non-free-flowing, cohesive system

the most difficult to mix well because of their tendency to unmix. Mixing time of five minutes was selected for all blending experiments thereafter, since it was a balance between two extremes, i.e., severe segregation for 1 min. mixing time and optimum mixture for 10 min. mixing time, and could accentuate any differences in the mixing variables.

Figure 4 shows the effect of an uneven leg of a V-shaped blender on the mixing efficiency. There are noticeable improvements of mixedness by leg reduction of 10% and 20% for both mixing models. Some variations in the data sets, e.g., 60% leg

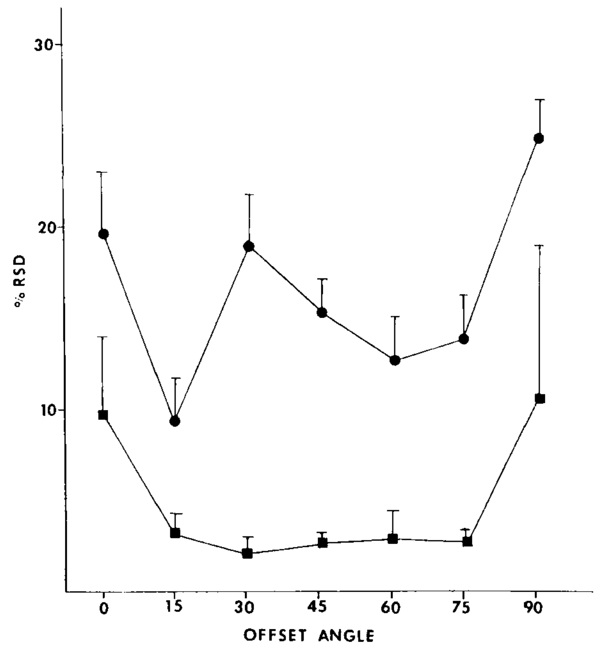

FIGURE 5
Effect of offset angle on the mixedness of the free flowing, segregating and non-free-flowing, cohesive mixing systems for five min. mixing runs.

● the free flowing, segregating system
■ the non-free-flowing, cohesive system

reduction for the cohesive model, exist. This may be caused by small agglomerates of sodium salicylate retaining their structure throughout the mixing process. However, the general trend of the profile for the cohesive model is quite similar to that for the segregating model. The cohesive mixture consistently shows better quality of mix than that of the free-flowing system.

The relative standard deviations from the measured means for both mixing models were plotted against various offset angles, as shown in Figure 5. The data for both mixing systems consistently reveal that the offset angle is a more effective means to modify a V-shaped blender to achieve the higher degree of uniformity than the leg reduction design. Both leg reduction and offset angle modifications provide unequal displacement of material which can cause a strong sideway movement of material from one leg of the blender to the other, due to the different volume of the two legs and the different relative positions of the two legs during the rotation, respectively. However, the offset angle design has more sliding, rolling actions and stronger shear forces during the rotation, compared with the leg reduction design. The general trend of the profile for both mixing systems bears some similarity, except for the data points at 30^0 and 45^0 offset angles.

CONCLUSIONS

In spite of different sampling procedures, sample sizes and testing procedures used in the two separate mixing studies, it appears that the free-flowing, segregating materials may be used as a mixing model to predict the trend of the performance of a modified V-shaped blender for the non-free-flowing, cohesive materials. However, in the equilibrium state, cohesive mixture has much better quality of the mix than that of the free-flow system in terms of the scale and intensity of segregation. The interparticle forces, e.g., electrostatic forces, van der Waals' forces and moisture bridging, in these two mixing systems differ widely in their extent. Due to the fundamental differences between two systems, direct extrapolation of the data generated from the free-flowing system to non-free-flowing system is not recommended.

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