THE EFFECT OF TRACER PARTICLE SIZE ON FEED MIXING QUALITY

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Summary

Distribution of tracer particles in carrier conform to Poisson distribution and the effect of Poisson distribution on mixing uniformity can be reduced by increasing the tracer particle number per unit weight. In this paper, above-mentioned theory has been demonstrated by using three kinds of rotor whose pitches are different.

(Key Words: The Tracer Particle Number Per Unit Weight, The Poisson Distribution Effect**)**

Introduction

With the precise requirement for livestock raising and the thorough study of feed machines, it becomes important to research the effect of test conditions on mixing quality, as effect of Poisson distribution of tracer particle size can result in system error in mixing effect. In order to reflect the quality of the mixer correctly, it is necessary to further study the test conditions of mixing uniformity. As the test conditions vary with the feed requirement, the methyl violet is chosen only in this study of the Poisson distribution effect on mixing uniformity.

Materials and Methods

Corn meal

The corn meal ground by hammermill with a 2 mm screen has been chosen. The corn meal specifications are as follows:

The average particle diameter	d=0.33 mm
Particle homogeneity index	s_g=2.6
Bulk gravity	r=0.7-0.75 g/cm^3
Content of moisture	w=13%.

Curves of particle-size distribution of the corn meal are shown in figure 1 and figure 2. The test has been done three times, so there are three curves in each figure and they changed into one curve eventually.

Tracer

The methyl violet is chosen as the test tracer. It is ground, sifted by screen with 120-, 150-, 200- and 320-mesh and then 0.5 g of sieved tracer is weighed for each test respectively. The following physical characteristics of the methyl violet are described.

a. Specific gravity is 1.3 g/cm^3.
b. Particle size distributions obey normal distribution

and some specifications of the methyl violet particle are given in table 1.

The number of methyl violet particle and its average particle diameter should conform to the following relation:

$$N = 6G/(\pi r d^3)$$

Where

N=the number of methyl violet particle, grain

TABLE 1. SPECIFICATIONS OF THE METHYL VIOLET PARTICLE

Mesh	Particle size range (μm)	Average diameter (μm)
120	0–125	62.5
150	0–100	50
200	0– 74	70
320	0– 50	25

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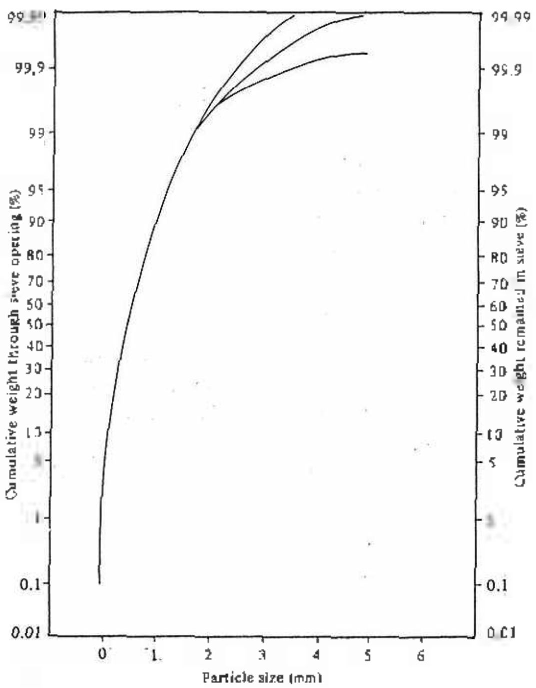

Figure 1. Logarithmic normal distribution of the corn meal particle.

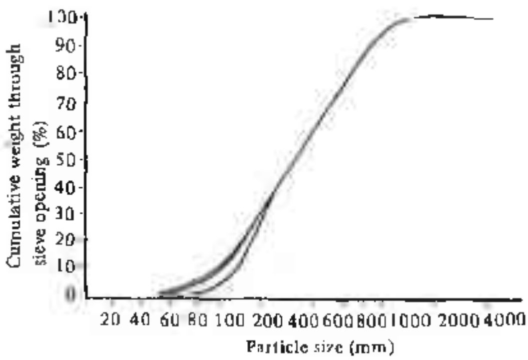

Figure 2. Cumulative particle-size distr'bution of the corn meal.

G=methyl violet weight, g
d=average particle diameter, mm
r=specific gravity of methyl violet, g/cm^3

Figure 3 shows the relationship between theoretical content of methyl violet particles and their average diameters.

Equipment

The 9WJ50 mixer which can blend 50kg/batch corn meal is chosen as test prototype machine

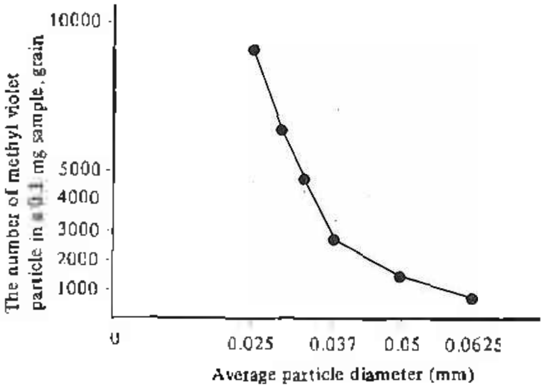

Figure 3. Relationship between the number of methyl violet particle and its average diameter.

(figure 4). The spiral-shaped mixing rotor rotates in a horizontal mixer trough, the two spirals move materials in opposite direction. This action causes an intense blending of the materials and a homogeneous mixture can be obtained.

Some specifications of the mixer are shown in table 2.

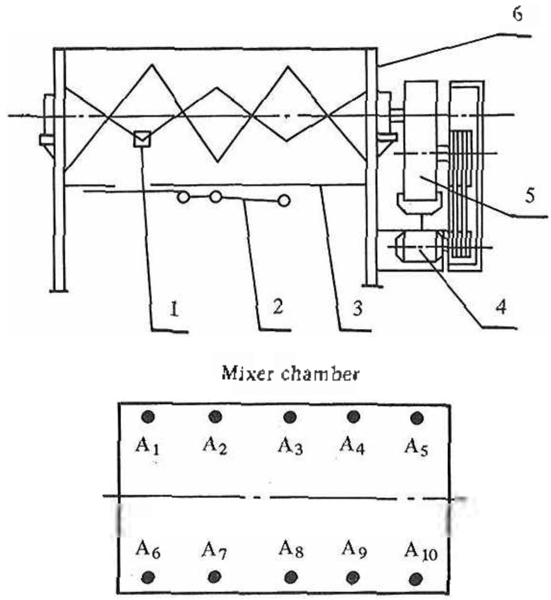

Figure 4. 9WJ50 batch mixer.

1. Adjusting ribbon
2. Discharge door
3. Rotor
4. Electric motor
5. Gear box
6. Housing

TABLE 2. SPECIFICATIONS OF THE MIXER (mm)

Rotator pitch	330	440	660
Width of external ribbon	20	20	20
Width of internal ribbon	40	40	40
Length of internal adjusting ribbon	127	185	127

Note: The internal ribbon can be adjusted to any width by changing ribbon.

Procedures

Four kinds of methyl violet sieved by 120-, 150-, 200- and 320-mesh screen were used in testing three kinds of rotor, whose pitches are 330, 440 and 660 mm in case of material horizontal plane having been stable, adjusted by the internal adjusting ribbon. Materials which contained corn meal and each mesh methyl violet were blended 1, 2, 3, ..., 6 minutes with each kind of rotor respectively, then take 10 samples from every batch mixture, the sites where the samples were taken have been shown in figure 4 as $A_1, A_2, A_3, \ldots A_9, A_{10}$.

Calculations.

The coefficient of variation is defined as

$$cv = s/m$$

where

s=standard deviation of the samples,

$$\sqrt{(\sum_{i=1}^{n} X_i^2 - nmx^2)/(n-1)}$$

m=mean value of the samples, $\sum_{i=1}^{n} X_i/n$

x_i=value of the i'th sample

n=number of the samples

$\sum_{i=1}^{n}$ =sum all n values

Results and Discussion

It has been proved that the variation in particle sizes of the corn meal and the methyl violet belongs to normal distribution. For the different ingredients with the same particle-size distribution, the double-term distribution gradually changes into the Poisson distribution during mixing process.

One particular characteristic of the Poisson distribution is:

$$s^2 = m$$

Hence the coefficient of variation for a Poisson distribution is:

$$cv = s/m = \sqrt{m}/m = 1/\sqrt{m},$$

if m is expressed with the number of tracer particles (N), then $cv = 1/\sqrt{N}$ (figure 5).

According to the requirement for uniformity of formula feed and premixing feed, standard deviation and coefficient of variation due to the Poisson distribution of the tracer particle size should conform to the following relations.

$$s \leqslant s^*, \quad cv \leqslant cv^*.$$

where

s = standard deviation of normal distribution of the sample

s* = theoretical standard deviation due to the Poisson distribution

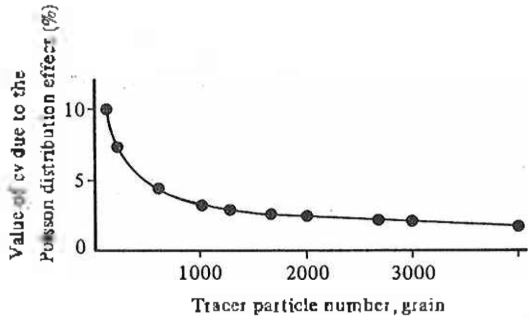

Figure 5. The effect of tracer particle number on coefficient of variation.

cv = coefficient of variation of normal distribution of the sample

cv* = coefficient of variation due to the Poisson distribution

Generally, cv $\leqslant$ 10% for the formula feed and cv $\leqslant$ 5% for the premixing feed, they are of mixture of the corn meal and tracer distribution.

It has been stipulated by some criterions that the tracer particle number should contain 1100 in a 10 g sample at least. Therefore, the coefficient of variation should be equal to $1/1100^{1/2} \times 100\%$, i.e. 3.01 %.

The ratio between cv for formula feed due to the Poisson distribution and the total cv is 3.01/10x100%, i.e. 30.1%. Likewise the proportion for the premixing feed is 3.01/5x100%, i.e. 60.2%.

From above the error resulted from the Poisson distribution effect is quite considerable, particularly the coefficient of variation for the premixing feed cannot correctly reflect the mixing quality.

According to the method of equal precision, the effect of Poisson distribution on the premixing feed should be controlled within 1.5%, so the number of tracer particles in a 10 g sample should be:

$$N = 1/cv^2 = 1/0.015^2 = 4{,}444.$$

On the basis of a proportion of the tracer added being 1/100,000 and the relationship between the average particle diameter and the content of the tracer particles in sample, the average particle diameter should be 0.032 mm.

In order to get a favourite uniformity of premixing feed, the sieve of 0.0634 mm opening should be used to sift the tracer particles.

Test results are shown in table 3 and figure 6.

From table 3 and figure 6 the mixing qualities of 330 mm- and 440 mm-pitch rotors are stabler and the values of cv are less than 10%, so the effect of Poisson distribution on mixing qualities of the two rotors is analysed only (table 4). Curves of their mixing uniformity are showed in figure 7 and figure 8.

TABLE 3. MESH, PITCH AND COEFFICIENT OF VARIATION

Pitch (min)	Mesh	Value of cv (%)
330	120	$3.75^{+1.46}$
	150	$3.26^{+3.32}$
	200	$1.98^{+0.98}$
440	120	$6.84^{+1.04}$
	150	$3.96^{+1.12}$
	200	$2.43^{+2.07}$
660	320	$2.53^{+2.14}$
	120	$9.565^{+8.235}$

Note: "+" represents the maximum value of cv.

From table 4, figure 7 and figure 8 the measured values of coefficient of variation vary with the number of methyl violet particles in case of other factors being constant. When using methyl violet particles through 200-mesh screen, the values of cv gained are not more than 5%. The more the number of methyl violet particle, the less the value

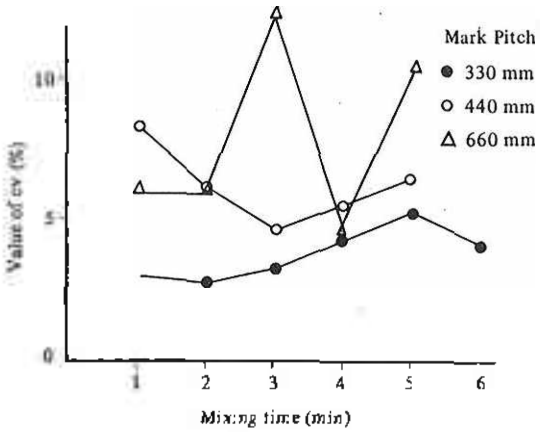

Figure 6. The effect of tracer particle number on uniformity of mixing.

TABLE 4. PITCH, MESH AND COEFFICIENT OF VARIATION

Pitch (mm)	Mesh	Average values of cv (%)
330	120	3.75
	150	3.26
	200	1.98
440	150	3.96
	200	2.43
	320	2.53

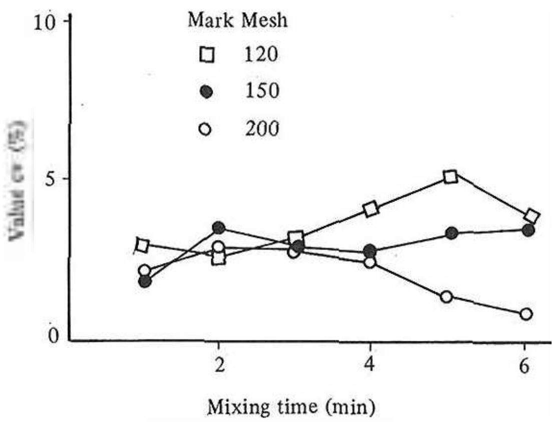

Figure 7. The curve of uniformity of 330 mm-pitch rotor.

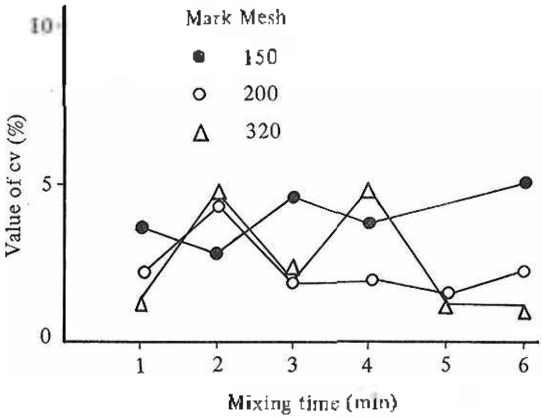

Figure 8. The curve of uniformity of 440 mm-pitch rotor.

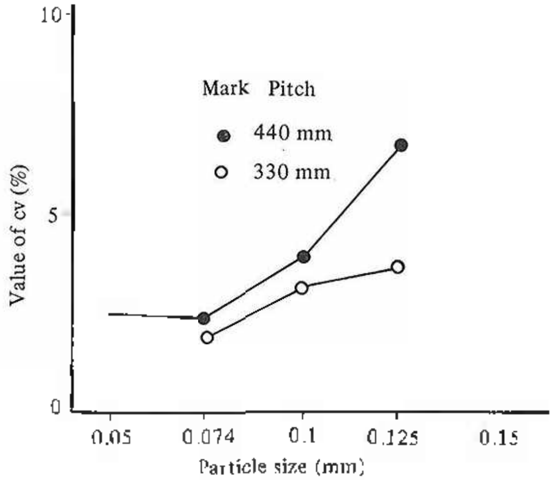

Figure 9. The effect of particle size on value of cv.

of cv, that is, the effect of Poisson distribution reduces with the increasing of the tracer particle number. Figure 9 shows the relationship between the tracer particle size and value of cv.

From the results of this work, the following conclusions can be drawn:

(1) To improve the mixing quality, in addition to making a study of structure and parameters of the batch mixer, the effect of Poisson distribution on mixing uniformity should be considered. The Poisson distribution effect can be reduced by using more tracer particles in case of a certain additive proportion.

(2) The tracer particle number varies with the requirements for feed, and the method of equal precision should be used to control the Poisson distribution effect.

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