

**EFFECT OF SIZE, SHAPE AND HARDNESS OF PARTICLES  
IN SUSPENSION ON ORAL PALATABILITY**

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**ABSTRACT**

The size, shape and hardness of particles in suspension can influence the oral sensory perception and palatability. This information can be used in the design of a suspension dosage form or to define optimal parameters for a reconstitutible oral delivery system. The report summarizes the effect of garnet, polyethylene and mica suspension on texture, taste and consistency. Significant differences in sensory perception exist between different samples based on the size, shape or hardness of the particles.

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## INTRODUCTION

The literature contains few citations directly discussing size, shape and hardness of particles in suspension and their influences upon oral sensory perception and acceptability. Most of the literature concerning particulates and their characteristics are concerned with dentifrices(1-3). Another body of literature focuses on the oral cavity and the sensation or perception of taste (4-7).

The oral cavity can be considered lined by a specialized extension of the skin. There are four different types of sensory receptors known; mechanoreceptors, chemoreceptors, thermoreceptors and receptors for electromagnetic radiation (8). Only the first three receptors are present in the oral cavity. The mechanoreceptors are the most involved with particle size, shape and hardness perception. Mechanoreceptors respond to physical stimuli that cause mechanical displacement of one or more tissues. Touch and pressure sensitive mechanoreceptors include Merkel's corpuscles (in the submucosa of the tongue and mouth), Meissner's corpuscles (beneath the surface of the skin), pacinian corpuscles (deep in the skin), free nerve endings (present in all tissues of the body) and other specialized mechanoreceptors (8,9).

The influence of the size, shape and hardness of particles on specific receptors in an individual's oral cavity has not been precisely defined. The confectionery literature views the minimum particle size which can be apprehended by the palate to

somewhere around  $25\ \mu$  (10). If the particles of a chocolate and all, or nearly all, are reduced below this size, the chocolate texture is considered to have reached optimum smoothness (11). Literature on particle size distribution indicates that a small proportion of particles up to  $65\ \mu$  gives better texture for milk chocolate whereas some good eating dark chocolate requires a maximum of  $35\ \mu$  (11). The chocolate particles are irregular and without sharp edges (11). While an individual's opinion is necessarily involved, it can be generally stated that smaller particle size enhances and "rounds out" flavor. The point of diminishing return is reached at sizes of about  $10\ \mu$  to  $15\ \mu$  (12). In the preparation of toothpaste, an average particle size of 5 to  $20\ \mu$  of alumina trihydrate is desirable because large particles can scratch the enamel surface and produce a gritty sensation in the mouth (13). The mouthfeel of the paste can be modified by using coarser or finer grades of alumina trihydrate.

In pharmaceuticals, such information is useful in the design of oral dosage forms, especially the identification of size, shape and hardness of particulates that would maximize the acceptability of a suspension by the minimization of any unpleasant sensation or to define the optimal microencapsule size range for oral drug delivery systems. The purpose of this investigation was to examine the influence of size, shape and hardness of particles in a suspension on oral sensory perception and palatability.

## MATERIALS AND METHODS

### Materials

Four different particle sizes for each of the three types of particulate matter: garnet, micronized polyethylene and mica particles coated with titanium dioxide, were examined. The shape was similar for each type of particulate matter. The particles were suspended in flavored syrup bases. Two different types of flavors, grape flavor and raspberry/cherry flavor were used in syrup bases. The particles were suspended in flavored syrup bases to give a concentration of 60 mg of test material/5 ml.

### Methods

Particle shape for each specimen was documented by Scanning Electron Microscopy (SEM) and particle size was determined by a laser diffraction (Malvern Instruments Series 2600C droplet and particle sizer).

For SEM, a sample from each test material was affixed to aluminum stubs using silver paint (Type: Silver Streaker™, Structure Probe, Inc.). Unsecured particles were blown free of the stub with compressed air. Specimens were sputter coated with gold-palladium (Hummer VI, Anatech Ltd.) and examined under the Scanning Electron Microscope (Model: JEOL JSM-T220A, 200-750X) (14).

Twenty-four or twenty-five adult volunteers participated in a single blind taste test for four

sensory evaluation tests (garnet/grape flavor, garnet/raspberry-cherry flavor, micronized polyethylene/raspberry-cherry flavor and mica/raspberry-cherry flavor). In each test, a total of five different samples were evaluated. Four different particle size distributions were evaluated against a placebo in each test. Each volunteer tested and expectorated three samples and a placebo. Samples in opaque bottles were well shaken immediately prior to dispensing a teaspoonful to each volunteer. Sample order was rotated to minimize order bias. Participants had unsalted crackers and water between samples to clear their palate. Respondents rated each sample on (a) texture, (b) taste and (c) consistency on a scale of 1 to 5. For a particular test, the flavor vehicle was the same for all samples but taste was included to determine the particle granule size may influence on taste perception. After rating each sample, volunteers were asked for their first choice except in the case of garnet particles suspended in grape flavored base where volunteers chose top two candidates.

Statistical analysis was performed by Statpad Software program utilizing ANOVA (analysis of variance) and Chi-Square Test (15).

### RESULTS AND DISCUSSION

The particle size for particulate matter studied are summarized in Table 1 and the SEM micrographs are presented in Figures 1-3. Garnet particles are generally hard and angular in shape. Micronized polyethylene is relatively soft and rounded in shape.

TABLE 1  
THE PARTICLE SIZE OF THE TEST MATERIALS

Sample	Garnet <sup>a</sup>		Micronized Polyethylene <sup>b</sup>		Mica Platlets Coated with Titanium Dioxide <sup>c</sup>	
	Mean Particle Diameter <u>D(50), (μ)</u>	<u>Span<sup>d</sup></u>	Mean Particle Diameter <u>D(50), (μ)</u>	<u>Span<sup>d</sup></u>	Mean Particle Diameter <u>D(50), (μ)</u>	<u>Span<sup>d</sup></u>
A	5.2	1.5	7.2	1.0	28.1	1.9
B	11.0	1.1	11.8	1.0	29.9	1.6
C	22.0	1.2	14.1	1.2	41.5	1.5
D	33.0	1.0	68.9	1.5	79.6	1.6

<sup>a</sup>Advanced Particle Measurements, Inc., Houston, Texas.  
<sup>b</sup>Allied Signal, Morristown, New Jersey.  
<sup>c</sup>McEairl Corporation, New York, New York.  
<sup>d</sup>SPAN = D(90) - D(10)/D(50).

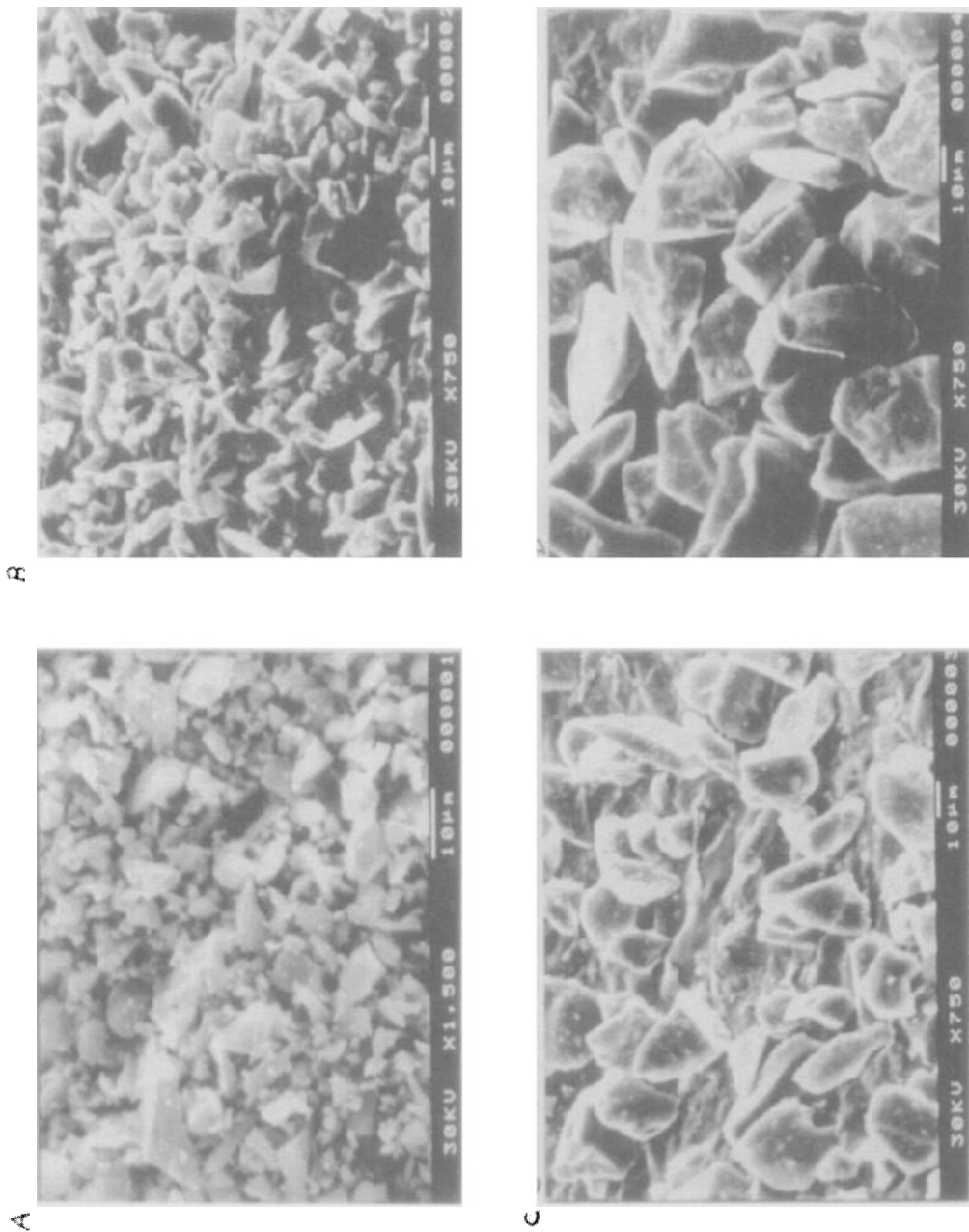


FIGURE 1 Scanning Electron Micrographs of Garnet Particles. The Mean Particle Size is (A) 5.2  $\mu$  (B) 11.0  $\mu$  (C) 22.0  $\mu$  and (D) 33.0  $\mu$ .

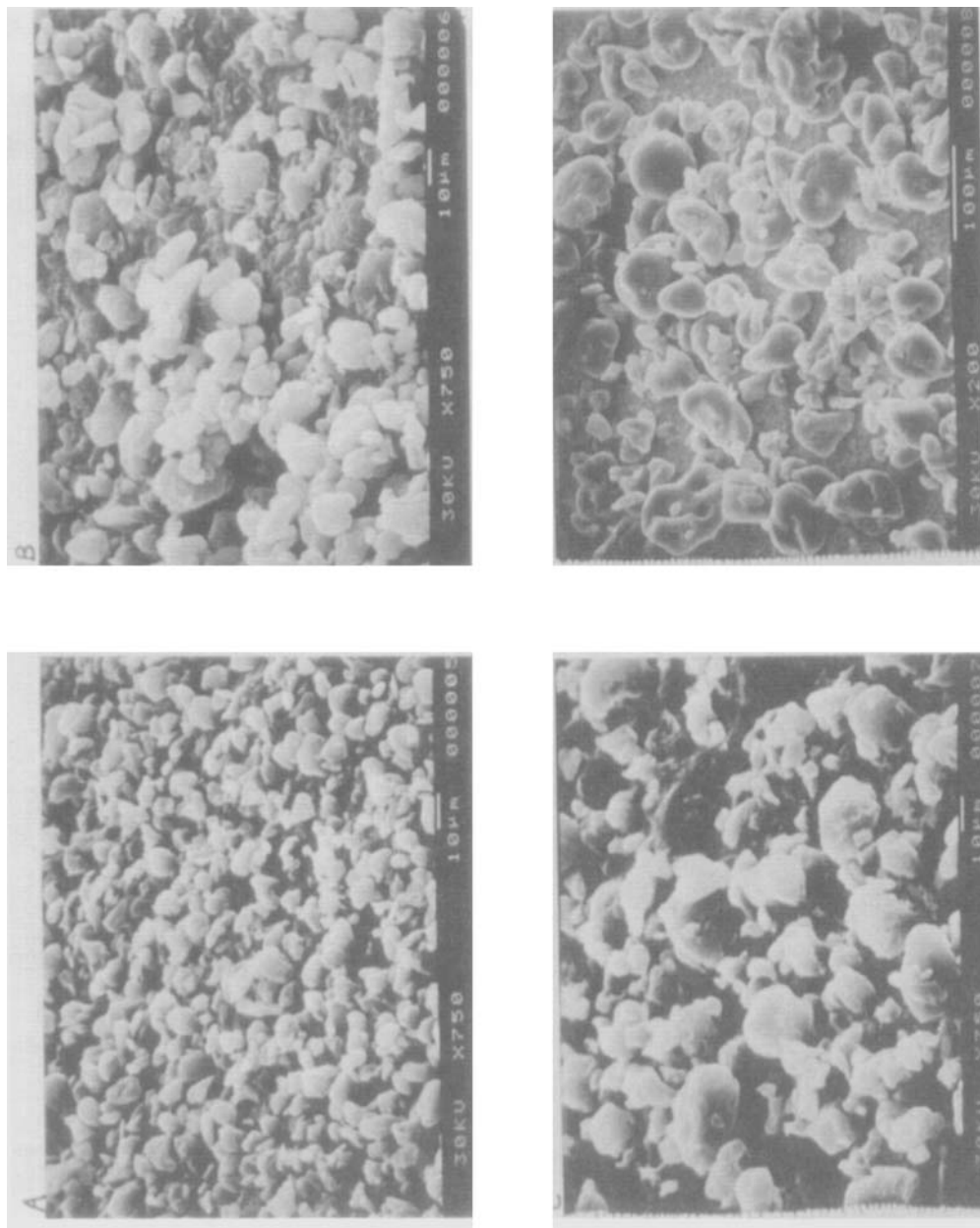


FIGURE 2 Scanning Electron Micrographs of Micronized Polyethylene Particles. The Mean Particle Size is (A) 7.2  $\mu$  (B) 11.8  $\mu$  (C) 14.1  $\mu$  and (D) 68.9  $\mu$ .



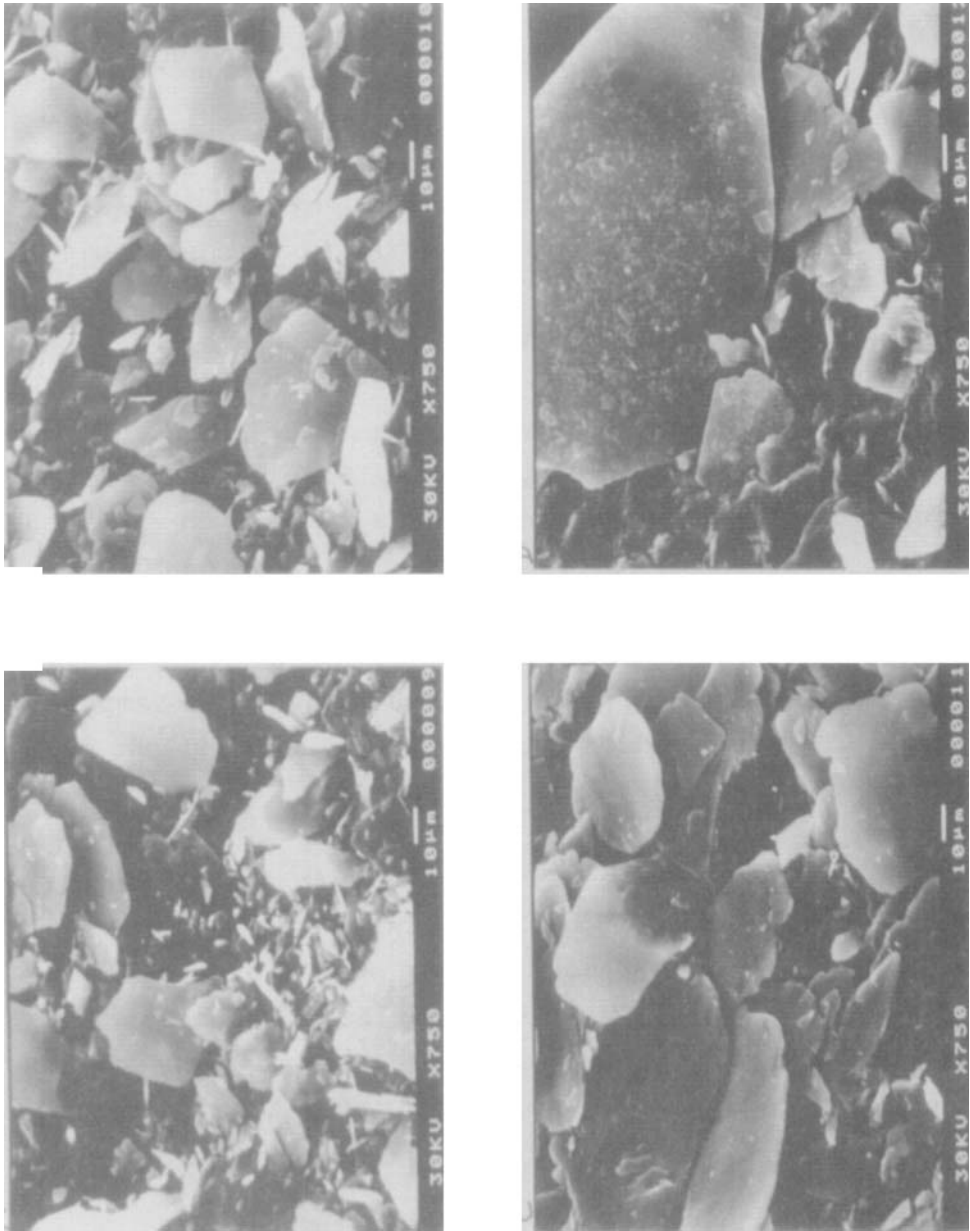


FIGURE 3 Scanning Electron Micrographs of Mica Particles. The Mean Particle Size is (A) 28.1  $\mu$  (B) 29.9  $\mu$  (C) 41.5  $\mu$  and (D) 79.6  $\mu$ .

Mica platlets coated with titanium dioxide are relatively hard and flat in shape. On the Mohs' scale of relative hardness, garnet has a hardness of 6.5-7, mica is 2.8 and micronized polyethylene is <2, as compared to talc's hardness of 1.0 and diamond being 10 (16).

The first test conducted examined garnet particulates in a grape flavored base. Table 2 summarizes the ratings for texture, taste and consistency. Table 3 shows an overall preference rating of the five samples tested. Granule size appears to be a factor in acceptance. As expected, the placebo (E) has the highest rating for texture. This is statistically significant over all other samples at the 95% confidence level. Sample A, with the second highest rating, is not statistically significant over any of the other samples at the 95% confidence level. It is, however, statistically significant over Sample C at the 93% confidence level and over D at the 84% confidence level. Using a scale of 1 to 5 where 1 means very unpleasant and 5 means very pleasant each sample was rated for taste. Sample E (placebo) has the highest rating, 4.1, but it is not statistically significant at the 95% confidence level over any of the other samples (Table 2). All samples are perceived to be about the right consistency. Any difference in consistency rating is not statistically significant at the 95% confidence level

After respondents rated the samples they were asked for their first and second choice (Table 3). As expected, the placebo was chosen most often. Using a

TABLE 2

RATINGS OF TEXTURE, TASTE AND CONSISTENCY FOR GARNET PARTICLES  
SUSPENDED IN GRAPE FLAVORED BASE

<u>Sample</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E<sup>a</sup></u>
	N=18	N=19	N=20	N=18	N=25
Average Texture Rating <sup>b</sup>	3.7±1.1	3.5±1.2	2.7±1.3	2.9±1.4	4.4±0.7
Average Taste Rating <sup>c</sup>	3.4±0.9	3.2±1.2	3.7±1.2	3.4±1.2	4.1±0.9
Average Consistency Rating <sup>d</sup>	3.2±1.0	3.1±0.6	3.1±1.0	3.4±1.0	3.1±0.8

Key:

All values are mean ± standard deviation.

<sup>a</sup>Sample E is placebo.

<sup>b</sup>Scale: 1 to 5 where 1 means gritty and 5 means smooth.

<sup>c</sup>Scale: 1 to 5 where 1 means very unpleasant and 5 means very pleasant.

<sup>d</sup>Scale: 1 to 5 where 1 means too thin and 5 means too thick.

TABLE 3

FIRST AND SECOND CHOICES COMBINED FOR  
GARNET PARTICLES SUSPENDED IN GRAPE FLAVORED BASE

N=24<sup>a</sup>

	Times Chosen <u>1st or 2nd</u>	# Times <u>Tasted</u>	% Time Chosen <u>1st or 2nd</u> <sup>b</sup>
Sample A	9	18	50.0%
B	7	19	36.8%
C	8	20	40.0%
D	6	18	33.3%
E (Placebo)	<u>18</u>	25	72.0%
Total	48		

<sup>a</sup>One subject did not respond to this question.

<sup>b</sup>Ratio of number of times chosen first or second to number of time tasted.

ratio of the number of times chosen first or second to the number of times tasted, Sample E was chosen 72.0% of the time that it was tasted, Sample A 50%; Sample C 40%; Sample B 36.8%, and Sample D 33.3%. The percents do not add to 100% because each sample is percented on a different base, i.e., the number of times it was tasted. The difference in preference is not statistically significant at the 95% confidence level.

The second test examined garnet but in a raspberry-cherry flavor primarily to determine the influence of change in flavor on the overall acceptance of particles. Table 4 shows ratings for texture, taste, and consistency. Table 5 tabulates choice for first preference.

Taste test participants seem to be able to detect the difference in particle size in these garnet samples. As Table 4 indicates, Samples A and B, which contain the smaller particles, have higher texture ratings than Samples C and D. As expected, the placebo (Sample E) has a very high rating of 4.5. Sample E is statistically significant at 95% confidence level over Samples B, C and D; Sample A is statistically significant over Samples C and D; and Sample B is statistically significant over Sample D at 95% confidence level. The best size for this test material appears to be between Samples B and C particle sizes (mean particle size = 11.0 to 22.0 microns). Each sample was rated on taste, the difference in the ratings is not statistically significant at the 95% confidence level. Most consistency ratings were about

TABLE 4

RATINGS OF TEXTURE, TASTE, AND CONSISTENCY FOR GARNET PARTICLES  
SUSPENDED IN RASPBERRY-CHERRY FLAVORED BASE

<u>Sample</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E<sup>a</sup></u>
	N=18	N=18	N=18	N=18	N=24
Average Texture Rating <sup>b</sup>	4.2±0.9	3.6±1.2	3.0±1.3	2.3±1.2	4.5±0.8
Average Taste Rating <sup>c</sup>	3.3±0.6	3.3±1.1	3.5±0.9	3.6±0.8	3.9±0.8
Average Consistency Rating <sup>d</sup>	3.2±0.8	2.9±0.7	3.6±0.7 <sup>e</sup>	3.1±0.6	3.1±0.6

Key:

All values are mean ± standard deviation

<sup>a</sup>Sample E is placebo.

<sup>b</sup>Scale: 1 to 5 where 1 means gritty and 5 means smooth.

<sup>c</sup>Scale: 1 to 5 where 1 means very unpleasant and 5 means very pleasant.

<sup>d</sup>Scale: 1 to 5 where 1 means too thin and 5 means too thick.

<sup>e</sup>One respondent didn't rate consistency.

TABLE 5

PREFERENCE FOR THE GARNET PARTICLES SUSPENDED  
IN RASPBERRY-CHERRY FLAVORED BASE

N=24

<u>Sample</u>	<u># Times Chosen</u>	<u># Times Tasted</u>	<u>% Time* Chosen</u>
A	3	18	16.7%
B	3	18	16.7%
C	3	18	16.7%
D	2	18	11.1%
E (Placebo)	12	24	50.0%
No Preference	<u>1</u>		
	24		

\*Ratio of number of times chosen to number of times tasted.

mid-point of 3.0. Although participants detect differences in particle size, average particle size does not appear to have much influence on consistency rating.

The only clear winner to emerge on overall preference was the placebo solution (Sample E). Twelve

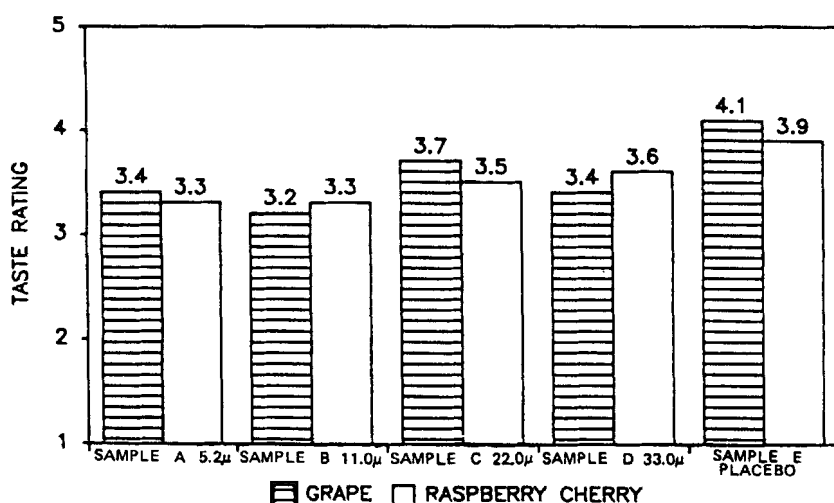


FIGURE 4

Comparison of Taste Acceptance of Grape Flavor vs. Raspberry Cherry Flavor Using Garnet Particles. The histograms are on a scale of 1 to 5 where 1 is very unpleasant and 5 is very pleasant.

of the 24 participants who tasted Sample E chose it as their preference, showing preference of solution over suspensions. The difference in preference is not significant at the 95% confidence level.

Figure 4 is a graph of taste acceptance of grape flavor vs. raspberry-cherry flavor, each with garnet. The flavor, grape or raspberry-cherry, seems to have little or no influence upon oral perception and acceptability of garnet texture, taste, consistency or preference. The upper acceptable particle size threshold is in the range between 11.0 microns and 22.0 microns (mean particle size diameter). This is



consistent with the range of abrasive powder (5 microns to 20 microns) used in dentifrices and the limiting size used in confectionery (10,13).

The third perception test examined micronized polyethylene in the raspberry-cherry flavored syrup base. Table 6 lists ratings for texture, taste, and consistency and Table 7 shows the choice of first preference.

The difference in particle size of polyethylene is apparently not detected by test participants. Texture ratings are not statistically significant at the 95% confidence level. Even though all samples were prepared with the same raspberry-cherry flavor, there are differences in taste perceptions. Sample E is statistically significant over Samples A and B at the 95% confidence level. When the placebo (E) is removed from the data set, the only statistical significance is Sample D over Sample A at the 95% confidence level. Some respondents commented on the plastic taste, especially those tasting samples A, B or C. The comments by volunteers include "off-flavor" and "very bitter after taste". It appears that each of the four average particle sizes (which arrived in four discrete samples) has an inherent contribution to the overall taste. Consistency ratings for all 5 samples were similar.

As shown in Table 7, the sample E was chosen most often as the first preference. The difference in preference is not statistically significant at the 95% confidence level. There does not appear to be an upper

TABLE 6  
RATINGS OF TEXTURE, TASTE AND CONSISTENCY FOR MICRONIZED POLYETHYLENE PARTICLES  
SUSPENDED IN RASPBERRY-CHERRY FLAVORED BASE

Sample	A	B	C	D	E <sup>a</sup>
	N=18	N=18N=18	N=18	N=24	
Average Texture Rating <sup>b</sup>	3.6±1.1	3.9±1.1	4.1±1.0	4.1±0.9	4.5±0.7
Average Taste Rating <sup>c</sup>	2.3±1.2	2.9±1.1	3.1±1.2	3.6±0.7	3.8±0.9
Average Consistency Rating <sup>d</sup>	3.2±0.7	3.4±0.8	3.3±0.8	3.5±0.6	3.2±0.6

Key:

All values are mean ± standard deviation.

<sup>a</sup>Sample E is placebo.

<sup>b</sup>Scale: 1 to 5 where 1 means gritty and 5 means smooth.

<sup>c</sup>Scale: 1 to 5 where 1 means very unpleasant and 5 means very pleasant

<sup>d</sup>Scale: 1 to 5 where 1 means too thin and 5 means too thick

TABLE 7

PREFERENCE FOR MICRONIZED POLYETHYLENE PARTICLES  
SUSPENDED IN RASPBERRY-CHERRY FLAVORED BASE

N=24

<u>Sample</u>	<u># Times Chosen</u>	<u># Times Tasted</u>	<u>% Time<sup>a</sup> Chosen</u>
A	3	18	16.7%
B	4	18	22.2%
C	1	18	5.6%
D	6	18	33.3%
E (Placebo)	<u>10</u>	24	41.7%
	24		

<sup>a</sup>Ratio of number of times chosen to number of times tasted.

threshold of particle size acceptability in the range of particle sizes of polyethylene studied. The mean particle diameter studied ranged from 7.2 microns to 68.9 microns.

The fourth test examined mica platelets coated with titanium dioxide in the raspberry-cherry flavored syrup

base. Table 8 shows ratings for texture, taste and consistency and Table 9 shows choice for first preference.

Under SEM, mica platlets coated with titanium dioxide are relatively angular and flat. As indicated in Table 8, all sizes of mica particles are well accepted on texture rating. The trend appears to show a decrease in rating with increase of average particle size, however, the difference is not statistically significant at the 95% confidence level. All samples have good ratings on taste. The difference in ratings is not statistically significant at the 95% confidence level. Consistency ratings for all samples are similar. The difference in ratings is not statistically significant at the 95% confidence level.

As expected, the placebo (Sample E) is chosen most often as overall preference. The difference in preference is not statistically significant at the 95% confidence level. With mica coated with titanium dioxide, the upper threshold of particule size acceptability was not detected in the range studied.

Figure 5 depicts the texture acceptability of garnet, micronized polyethylene, and mica using a raspberry-cherry flavored base. Micronized polyethylene and mica texture are more accepted over garnet when the materials were used in raspberry-cherry flavored bases. The ratings for the placebo sample in each of the test is similar showing that the variability between the tests is negligible.

TABLE 8

RATINGS OF TEXTURE, TASTE AND CONSISTENCY FOR MICA PLATLETS COATED  
WITH TITANIUM DIOXIDE SUSPENDED IN RASPBERRY-CHERRY FLAVORED BASE

<u>Sample</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E<sup>a</sup></u>
	N=18	N=18	N=18	N=18	N=24
Average Texture Rating <sup>b</sup>	4.0±1.0	4.1±1.0	3.8±1.2	3.6±0.9	4.4±0.7
Average Taste Rating <sup>c</sup>	3.7±1.0	3.8±1.0	3.5±1.2	3.3±1.0	3.7±1.1
Average Consistency Rating <sup>d</sup>	3.6±0.8	3.4±0.8	3.3±0.8	3.2±0.7	3.2±0.6

Key:

All values are mean ± standard deviation.

<sup>a</sup>Sample E is placebo.

<sup>b</sup>Scale: 1 to 5 where 1 means gritty and 5 means smooth.

<sup>c</sup>Scale: 1 to 5 where 1 means very unpleasant and 5 means very pleasant

<sup>d</sup>Scale: 1 to 5 where 1 means too thin and 5 means too thick

TABLE 9

PREFERENCE FOR MICA PLATLETS COATED WITH  
TITANIUM DIOXIDE SUSPENDED IN  
RASPBERRY-CHERRY FLAVORED BASE

N=24

<u>Sample</u>	<u># Times Chosen</u>	<u># Times Tasted</u>	<u>% Time<sup>a</sup> Chosen</u>
A	5	18	27.8%
B	5	18	27.8%
C	2	18	11.1%
D	3	18	16.7%
E (Placebo)	<u>9</u>	24	37.5%
	24		

<sup>a</sup>Ratio of number of times chosen to number of times tasted.

With hard garnet and mica particulates the data show that as the particulate size increases, the texture rating decreases. The trend seems reversed for relatively soft polyethylene particulates.

Figure 6 portrays the taste acceptability of garnet, micronized polyethylene and mica using the

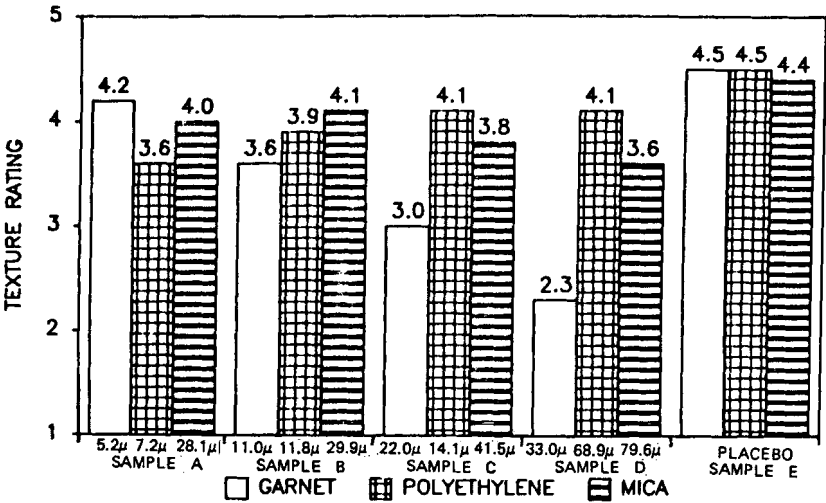


FIGURE 5

Comparison of Texture Acceptance of Garnet, Micronized Polyethylene and Mica is Raspberry Cherry Flavor. The mean particles size is shown below each histogram. The ratings are on a scale of 1 to 5 where 1 is gritty and 5 is smooth.

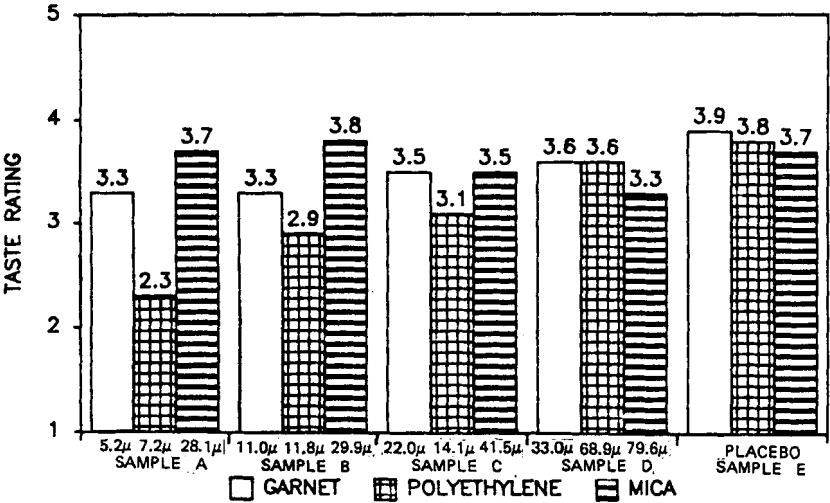


FIGURE 6

Comparison Taste Acceptance of Raspberry Cherry Flavor with Garnet Micronized Polyethylene and Mica Suspension. The mean particle size is shown below each histogram. The ratings are on a scale of 1 to 5 where 1 is very unpleasant and 5 is very pleasant.

raspberry-cherry flavored base. When micronized polyethylene was compared to garnet and mica in taste acceptability, garnet and mica were favored. It is speculated that this occurred because of an inherent taste effect that micronized polyethylene can render. The effect is greatest in sample suspensions with largest number of particulates.

The results obtained show that changes in flavor of the base with the sample particles do not effect the oral perception and that the oral perception of texture is influenced by particle size, shape and hardness. The particles which are generally soft and rounded or are relatively hard and flat are not perceived as gritty. On the other hand, with hard and angular particles, like garnet, grittiness is evident above a certain particle size range. The perception of the suspension should be the same within a set of samples if the particles do not effect the taste in any manner. This was true in case of garnet and mica suspension. However, micronized polyethylene seem to influence the taste of the samples over placebo. There was no effect observed on the consistency of the product after particulates were suspended in the flavored base.

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