Grayscale Method for Emulsifying Effect Testing

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Abstract. Emulsion is a semi-synthetic working fluid with high performance, whose chemical components mainly include water, base oil, surfactant, rust-inhibiting additive, etc. It has been widely used in industrial processing, but the assessment on its composition effect generally still depends on the intuitive evaluation method with eyes. However, the effect of this method is not accurate, which cannot be used for accurately determining the emulsification status in the experiment. Thus, other methods have been developed, such as droplet distribution test method, dielectric constant test method, conductivity test method and turbidity test method. This paper introduces a more simple and efficient emulsification evaluation method - grayscale method..

Experimental Method

Principle of Grayscale Analysis

The composition effect of emulsion mainly lies in its state, such as transparency, micro emulsion and delamination, so the chromatic aberration can be used for determining the degree of emulsification. The principle of grayscale analysis is as follows:

The prepared emulsion was grouped and numbered. The image software was used for gray processing, and then eight points were evenly selected to collect their grayscales. The variance of each number was mathematically calculated. The larger variance value indicated the worse effect of the numbered emulsion, and on the contrary, the smaller variance value indicated the better effect of the numbered emulsion, i.e. the better emulsifying effect.

Experimental Conditions and Method

Experimental apparatus: water bath kettle, stirrer, measuring cup, vacuum flask and syringe.

Emulsifying method: each vacuum flask was filled with 600ml of water and 60ml of base oil (paraffin). It took 20 minutes to prepare the emulsion, including 5 minutes for preheating, 5 minutes for stirring water and oil and 10 minutes for adding emulsifier and stirring. In the stirring process, the lipophilic emulsifier was added to the oil base and the hydrophilic emulsifier was added to the water. Then the prepared emulsion was kept still for one day. Finally, the grayscale method was used for the orthogonal experiment.

Orthogonal Experiment Validated Grayscale

Orthogonal Experimental Design

The experiment had three factors, the emulsifying temperature, the additive concentration and the ratio of Span-80 and Op-10. For Experiment 1, the temperature was 30 ℃, 50 ℃ and 70 ℃, the concentration was 1%, 5% and 10%, and the ratio was 1:4, 1:3 and 1:2.

For Experiment 2, the temperature was 70 ℃, 80 ℃ and 90 ℃, the concentration was 10%, 15% and 20%, and the ratio was 1:2, 3:4 and 1:1.

Experimental Results and Analysis

Results and Analysis of Experiment 1. As can be seen from the table, the three averages corresponding to the temperature are respectively 36.320, 20.690 and 6.120, so the emulsification conducted at 70℃ has the best emulsifying effect. Similarly, the optimum concentration of Experiment 1 is 10% and the optimum ratio is 1:2. The range in the orthogonal experiment reflects the influence of all factors on the experimental results. The greater range indicates more significant influence of the factor on the emulsifying effect. As can be seen from the above table, the ranges of temperature, concentration and ratio are respectively 30.200, 51.080 and 23.630, that is, the order of the influence of these three factors is concentration, temperature and ratio.

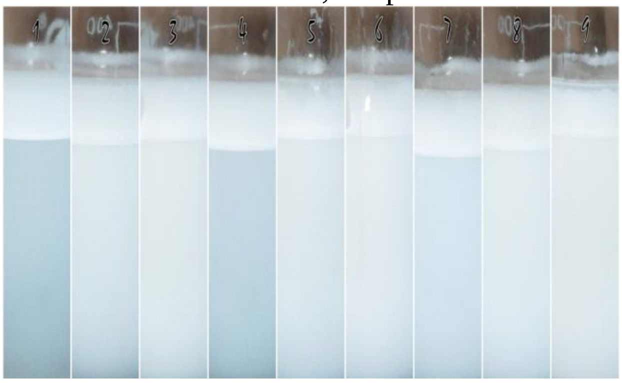

Fig.1 Emulsification effect

Tab.1 After image processing of the groups of grey value and the variance values

Grayscale / Number / Point	1	2	3	4	5	6	7	8	9
1	10	15	13	12	11	12	11	11	10
2	11	12	10	11	9	11	10	9	10
3	7	10	9	10	7	9	8	9	9
4	24	15	13	23	12	11	15	11	11
5	27	15	13	24	14	11	15	11	11
6	27	16	13	25	15	12	16	11	12
7	30	17	14	26	16	13	18	13	12
8	35	20	16	28	17	14	20	13	13
Variance	96.73	8.00	4.23	49.36	10.73	1.98	14.86	2.00	1.50

Tab.2 Orthogonal experimental analysis

Predisposition	Temperature(℃)	Consistence(%)	Ratio	Result
NO.1	30	1	1:4	96.73
NO.2	30	5	1:3	8.00
NO.3	30	10	1:2	4.23
NO.4	50	1	1:2	49.36
NO.5	50	5	1:4	10.73
NO.6	50	10	1:3	1.98
NO.7	70	1	1:3	14.86
NO.8	70	5	1:2	2.00
NO.9	70	10	1:4	1.50
Average 1	36.320	53.650	33.570	
Average 2	20.690	6.910	19.620	
Average 3	6.120	2.570	9.940	
Range	30.200	51.080	23.630	

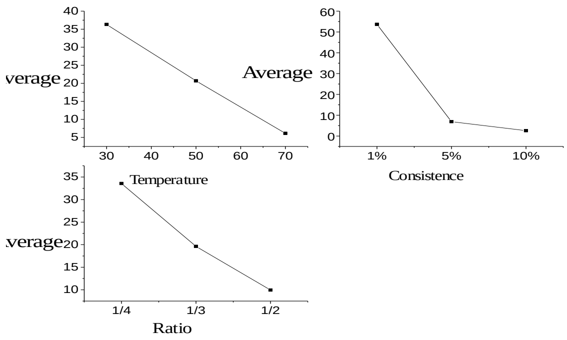

Fig.2 Factor diagram

The mean of each factor was respectively taken from Table 2 as the ordinate and the value of each factor as the abscissa. See Figure 2 for the relationship between them.

As can be seen from the figure, the increasing temperature has an increasing influence on the emulsifying effect, the increasing concentration has a decreasing influence on the emulsifying effect and the increasing ratio has an increasing influence on the emulsifying effect.

Results and Analysis of Experiment 2. The experimental results of the three factors are all monotone decreasing, indicating that the above orthogonal experimental design does not fully cover the influence scope of the experimental results. In order to further improve the influence rule of each experiment, the maximum value of Experiment 1 was taken as the starting point to design the second orthogonal experiment so as to explore the complete influence of various factors on the experimental results.

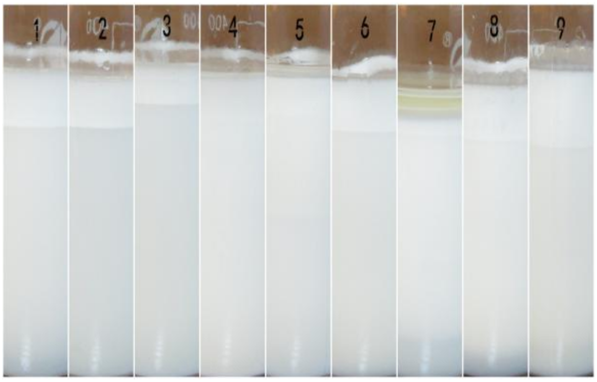

Fig.3 Emulsification effect

Tab.3 After image processing of the groups of grey value and the variance values

Grayscale \ Number / Point	1	2	3	4	5	6	7	8	9
1	15	15	15	20	17	16	28	16	14
2	13	15	15	18	15	15	28	14	14
3	13	15	15	16	14	14	13	13	14
4	14	20	17	16	15	17	13	14	18
5	16	21	20	17	15	17	13	14	18
6	18	22	21	17	16	17	15	15	20
7	18	23	22	17	18	17	16	17	20
8	24	23	23	18	22	19	25	25	24
Variance	11.73	11.69	12.86	1.48	5.75	2.00	41.36	13.00	11.44

For Experiment 2, the temperature was 70 ℃, 80 ℃ and 90 ℃, the concentration was 10%, 15% and 20%, and the ratio was 1:2, 3:4 and 1:1.

The table of orthogonal experimental analysis shows the influence of temperature, concentration and ratio on the emulsifying effect. The smaller value of data in the experiment indicates better influence on the emulsifying effect. As can be seen from the table, the three averages corresponding to the temperature are respectively 3.077, 8,767 and 9.113, so the emulsification conducted at 80 ℃ has the best emulsifying effect. Similarly, the optimum concentration of Experiment 1 is 20% and the optimum ratio is 3:4. As can be seen from the above table, the ranges of temperature, concentration and ratio are respectively 18.856, 9.423 and 11.787. The greater range indicates more significant influence of the factor on the emulsifying effect, that is, the order of the influence of these three factors is temperature, concentration and ratio.

Tab.4 Orthogonal experimental analysis

Predisposition	Temperature(℃)	Consistence(%)	Ratio	Result
NO.1	70	10	1:2	11.73
NO.2	70	15	3:4	11.69
NO.3	70	20	1:1	12.86
NO.4	80	10	1:1	1.48
NO.5	80	15	1:2	5.75
NO.6	80	20	3:4	2
NO.7	90	10	3:4	41.36
NO.8	90	15	1:1	13
NO.9	90	20	1;2	11.44
Average1	12.093	18.190	8.910	
Average2	3.077	10.147	8.203	
Average3	21.933	8.767	19.990	
Range	18.856	9.423	11.787	

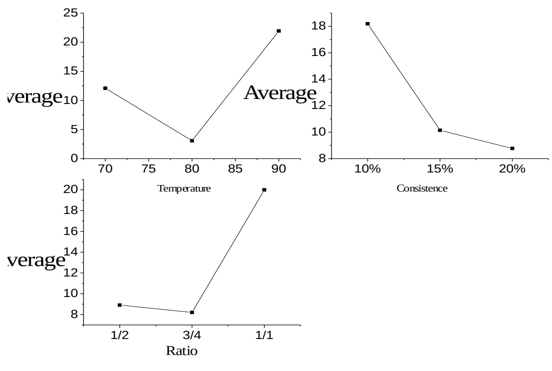

Fig.4 Factor diagram

The mean of each factor was respectively taken from Table 4 as the ordinate and the value of each factor as the abscissa. See Figure 4 for the relationship between them.

The influence of the three factors on the emulsifying effect can be clearly seen from the figure. The inflection point appears in the temperature curve, so the peak indicates that the optimum temperature is 80 ℃ and the temperature below or above it will reduce the emulsifying effect. Similarly, the inflection point also appears in the ratio curve, so the peak ratio 3:4 is the optimum emulsification value and the ratio below or above it will reduce the emulsifying effect. As can also be seen from the figure, the change in the concentration has a monotonic influence on the emulsifying effect. The higher concentration means the better emulsifying effect, which tends to be gentle.

The grayscale method was used for evaluating the above experimental results to determine the optimum conditions for emulsification. According to the literature reviewed, the optimum emulsifying temperature of paraffin is generally 50-85 ℃, and the optimum temperature determined by the grayscale method is consistent with the above temperature range. And as can be seen from the literature, different organic matters have different concentrations for emulsification. The influence is monotonic, that is, the higher the concentration, the better the emulsifying effect. The rule of concentration obtained from the experiment is consistent with the above-mentioned rule.

Conclusion

This paper uses the grayscale analysis and the orthogonal experiment to analyze the experimental results in combination with the experimental results of others and reaches the following experimental conclusions:

1) It is found in the grayscale analysis of the experimental results that the optimum temperature and ratio in the experiment are at the inflection points of the curve, that is, the optimum temperature is 80 ℃ and the optimum ratio is 3:4. The concentration has a monotonic influence on the experiment and tends to be gentle at last, that is, the higher the concentration, the better the emulsifying effect.

2) It is further found that the influence of temperature is greater than that of the ratio and concentration on the emulsifying effect.

The consistent experimental results and emulsification rule validate the feasibility of grayscale method.

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