Analysis of the Results of Proficiency Testing for the Determination of Total Zinc and Metallic Zinc in Zinc Powder

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Abstract: ***A proficiency testing for the determination of total zinc and metallic zinc in zinc powder was carried out to examine the testing capabilities of each participating laboratory for the two parameters of total zinc and metallic zinc in zinc powder according to GB/T 6890-2012 "Zinc Powder". A total of 31 laboratories participated in this proficiency testing. Robust statistical analysis was performed on the results returned by the laboratories. The median value was used as the assigned value, and the normalized interquartile range (NIQR) was used as the standard deviation for proficiency assessment. The results of each laboratory were evaluated by the z-score. The results showed that for the total zinc parameter, the results of 27 laboratories were acceptable, and the results of 4 laboratories were problematic, with a satisfaction rate of 87.1%; for the metallic zinc parameter, the results of 28 laboratories were acceptable, the results of 2 laboratories were problematic, and the results of 1 laboratory were unacceptable, with a satisfaction rate of 90.3%. Factors such as the weighing and dissolution of samples, the instruments and reagents used, the titration operation process, and temperature can all affect the test results.***

Keywords: Zinc powder; Total zinc; Metallic zinc; Proficiency testing; Result analysis.

1. INTRODUCTION

Zinc powder has important applications in fields such as coatings, chemical engineering, and metallurgy. The total zinc content and metallic zinc content are two important parameters for evaluating the performance of zinc powder. The total zinc content refers to the content of all forms of zinc in the sample, and the metallic zinc content refers to the content of elemental zinc in the sample. Both of them affect the product quality and production process. Therefore, the accurate determination of the total zinc content and metallic zinc content in zinc powder is an important factor in ensuring product quality. There are various testing methods for the determination of zinc content in zinc powder, such as chemical titration method , differential scanning calorimetry, atomic absorption spectrometry , inductively coupled plasma emission spectrometry , spectrophotometry, etc.. For zinc powder with a high zinc content, the chemical titration method is the most commonly used and convenient analysis method. The method for determining the zinc content in zinc powder by chemical titration is mainly carried out according to GB/T 6890-2012 "Zinc Powder". The method for determining the total zinc content in zinc powder by chemical titration is to dissolve the test sample with hydrochloric acid and hydrogen peroxide, add an acetic acid-sodium acetate buffer solution (pH value is 5~6) and xylenol orange indicator, and titrate with a standard solution of disodium ethylenediaminetetraacetate (Na_2EDTA). The end point of the titration is when the solution turns bright yellow; the method for determining the metallic zinc content in zinc powder by chemical titration is to react the metallic zinc in the test sample with ferric sulfate to generate an equivalent amount of ferrous sulfate, and indirectly calculate the metallic zinc content in the test sample by titrating with a potassium permanganate $KMnO_4$ standard solution. Proficiency testing is a qualified assessment activity to determine the detection or calibration ability through inter-laboratory comparison. This proficiency testing plan is to verify and evaluate the detection capabilities of each participating laboratory for measuring the two parameters of the total zinc content and metallic zinc content in zinc powder, evaluate the capabilities of the testing personnel for detecting various items of such products, and at the same time, it is also an evaluation of the consistency of the quantitative detection of the total zinc content and metallic zinc content among different laboratories. Wang and Lai (2026) proposed a strategy to enhance upper-room ultraviolet germicidal irradiation (UVGI) performance by employing a rotating UV source under poorly-mixed ventilation conditions, aiming to improve disinfection efficacy in spaces with uneven airflow [1]. Narouei et al. (2025) investigated the effects of germicidal far-UVC (222 nm) on ozone and particulate matter in a conference room, revealing that the irradiation not only inactivates microorganisms but also induces secondary chemical reactions that alter ozone and particle concentrations, thereby raising important concerns for indoor air quality [2]. Xiao et al. (2022) developed an ultrasmall Fe_3O_4-decorated polydopamine hybrid nanozyme that enables continuous conversion of dissolved oxygen into highly toxic hydroxyl radicals via a glutathione-depleted cascade redox reaction, and they demonstrated its intensive wound disinfection capability with promising biocompatibility [3]. Zhang and Lai (2026) explored a synergistic approach by combining far-UVC with negative air ions in a portable device, showing that this dual-mode system can achieve enhanced air disinfection performance compared to either method alone [4]. Mogensen et al. (2025) evaluated ceiling-mounted far-UVC fixtures in occupied clinical areas, finding that such installations significantly reduced surface bioburden without adverse effects on patients or staff [5]. Finally, Ross et al. (2023) examined public acceptance of far-UVC technology for virus inactivation, identifying key challenges such as safety perceptions and regulatory hurdles, while also highlighting opportunities for education and policy development to facilitate broader adoption [6]. Chen Xinlei (2023) offered thoughts on grassroots archival management in the big data era, emphasizing practical improvements [7]. Sun Huanying (2023) reflected on the construction of digital archives, discussing practices and lessons learned [8]. Jiang and Huang (2022) analyzed the comprehensive characteristics of archival data mining, focusing on big data applications [9]. Xu and Wang (2023) explored the digital transformation of archival management in the information age, suggesting strategies for transition [10]. Finally, Xiao Yanli (2022) researched the data transformation of archival management from an internet perspective, proposing new models for integrating online resources [11].

2. PROFICIENCY TESTING DESIGN PLAN

(1) Purpose and significance of this plan. The main purpose of this plan is to evaluate the ability of laboratories to detect the total zinc content and metallic zinc content in zinc powder in accordance with GB/T 6890-2012 "Zinc Powder", and to provide a means for laboratories to consider and confirm the reliability of their test data. This plan can help the testing personnel of participating laboratories discover problems existing in their daily testing in this field and make improvements, thereby enhancing the testing capabilities of the participating laboratories.

(2) Sample selection and homogeneity and stability testing. This plan requires laboratories to determine the total zinc content and metallic zinc content of zinc powder. The testing is carried out in accordance with Appendix A and Appendix B of GB/T 6890-2012 "Zinc Powder". A certain brand of first-grade zinc powder is selected as the sample for this plan, with a particle size of approximately 30 um, a total zinc content of not less than 98%, and a metallic zinc content of not less than 96%. After mixing the zinc powder evenly, it is packed in white polyethylene bottles, about 2 g per bottle, and numbered in sequence. One bottle of zinc powder sample is provided for each laboratory for the detection of total zinc content and metallic zinc content.

Before sending the samples, the implementing agency conducted tests on the homogeneity and stability of the samples. The method for the homogeneity test was as follows: 12 units were randomly selected from the samples, and the total zinc content and metallic zinc content of the samples were tested according to Appendix A and Appendix B of GB/T 6890-2012 "Zinc Powder" respectively. The selected samples were tested twice under repeated conditions, and the one-way analysis of variance method was used to statistically process the test results. The results showed that at the 0.05 significance level, the total zinc content parameter and metallic zinc content parameter of the samples were both homogeneous; after the results of this round of proficiency testing were recovered, the recovery laboratory returned the data, and the standard deviation between samples S_s was compared with the standard deviation for proficiency assessment σ for homogeneity verification. The results showed that $S_s \leq 0.3\sigma$, the uncertainty introduced by the inhomogeneity of the samples could be ignored. Therefore, it was considered that the proficiency testing samples had sufficient homogeneity. The stability test was judged by using the t test. The results obtained from the homogeneity test were the first measurement data for the stability test; then, before the samples were transferred, a simulated high and low temperature stability test was conducted on the samples, and the results obtained were the second and third data for the stability test; after each participating laboratory fed back the result data to the organizing agency, 6 bottles of samples were randomly selected for testing, and the test results were the fourth data for the stability test. The results showed that the t values of the total zinc content and metallic zinc content parameters were both less than $t_{0.05}$ (16). It can be seen that the total zinc content parameter and metallic zinc content parameter of the samples were stable. Therefore, the homogeneity and stability of the samples were both good, and the unsatisfactory results in this proficiency testing plan were not caused by sample differences.

3. STATISTICAL PROCESSING RESULTS AND PROFICIENCY EVALUATION

(1) Implementation of this plan. A total of 33 laboratories signed up for this proficiency testing plan. Among them,

two laboratories used the DSC method for testing, which did not meet the requirements of this proficiency testing method and were not included in the statistics. A total of 31 sets of valid data were obtained. For confidentiality reasons, each participating laboratory was assigned a code in this proficiency testing plan. When analyzing the results, each participating laboratory was represented by its code.

(2) Determination of the assigned value and the standard deviation of proficiency evaluation. The assigned value and the standard deviation of proficiency evaluation were determined based on the results of the participants in the proficiency testing plan. The test results of each participating laboratory were evaluated using the z value, which was calculated according to Equation (1). When $|z| \leq 2.0$, the result was considered acceptable (satisfactory); when $2.0 < |z| < 3.0$, it indicated that there was a problem with the result, a warning signal was generated, and it was marked with "*"; when $|z| \geq 3.0$, it indicated that the result was unacceptable (unsatisfactory), an action signal was generated, and it was marked with "§".

$$z = \frac{x - X}{\sigma}$$

In the formula, x is the laboratory result, % ; X is the assigned value, % ; σ is the standard deviation of proficiency evaluation, %.

When analyzing the data, the assigned value and the standard deviation of proficiency evaluation were determined through robust statistical techniques , that is, the median value was used as the assigned value, and the normalized interquartile range (NIQR) was used as the standard deviation of proficiency evaluation.

(3) Result evaluation. A total of 31 laboratories submitted their test results in this plan. The statistics of each parameter are shown in Tables 1 and 2.

Table 1: Statistical Summary Table of Determination Data for Total Zinc Content

Number of results / piece	Robust mean value / %	σ / %	Maximum value / %	Minimum value / %	Range / %
31	98.74	0.523	99.90	97.46	2.44

Table 2 Statistical Summary Table of Parameter Determination Data for Metallic Zinc Content

Number of results / piece	Robust mean value / %	σ / %	Maximum value / %	Minimum value / %	Range / %
31	97.10	0.812	98.97	94.05	4.92

Statistics of the Determination Results of Total Zinc Content

z - score	Laboratory code	Proportion value
$\|z\| \leq 2$	010203404506081011121314 16 17 20 21 22 23 25 26 27 28 30 31 32 33 34	87.1%
$2 < \|z\| < 3$	15 19 24 29	12.9%
$\|z\| \geq 3$		0%

Statistics of the Determination Results of Metallic Zinc Content

z - score	Laboratory code	Proportion value
$\|z\| \leq 2$	010203404506081011121314 16 17 19 20 21 22 23 24 26 27 28 30 31 32 33 34	90.3%
$2 < \|z\| < 3$	1529	6.5%
$\|z\| \geq 3$	25	3.2%

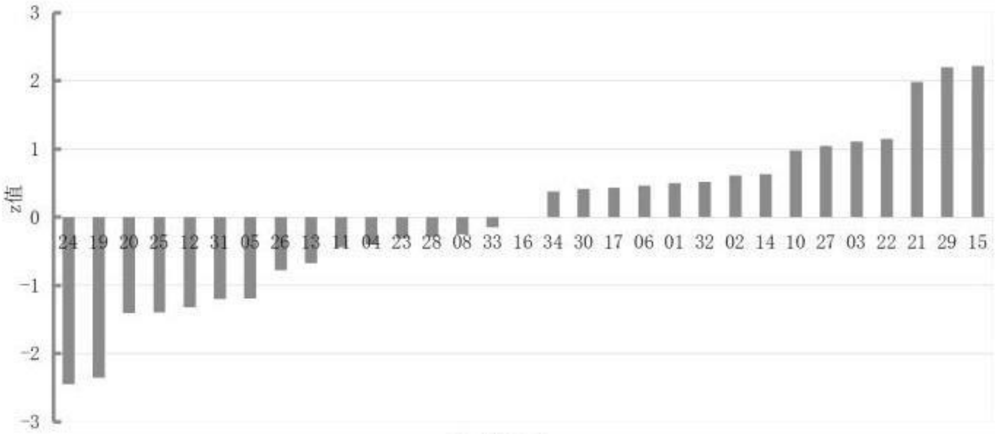

Figure 1: Bar chart of the ratio score of the total zinc content parameter

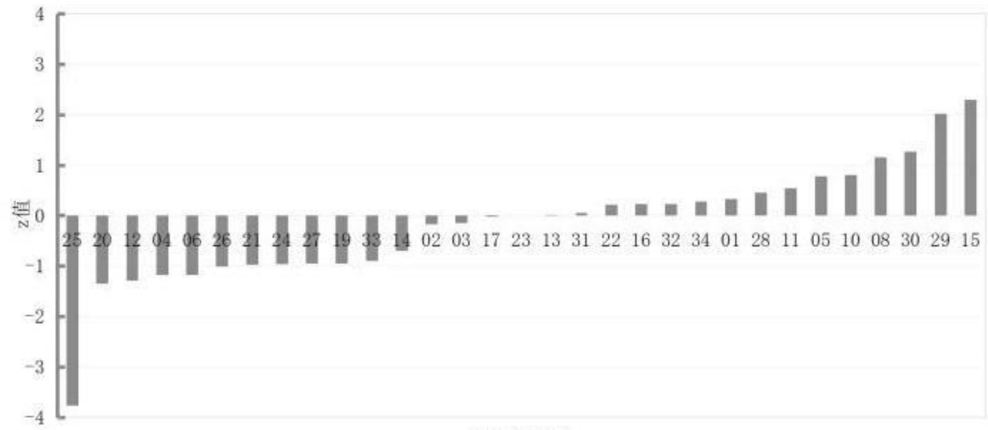

Figure 2: Graph of the ratio score of the metallic zinc content parameter

The statistical results of this plan are shown in Tables 3 and 4. For the total zinc content parameter, 27 laboratories had acceptable results and 4 laboratories had problematic results, with a satisfaction rate of 87.1%. For the metallic zinc content parameter, 28 laboratories had acceptable results, 2 laboratories had problematic results, and 1 laboratory had unacceptable results, with a satisfaction rate of 90.3%. The z-ratio score bar charts of the participating laboratories are shown in Figures 1 and 2.

4. TECHNICAL ANALYSIS AND SUGGESTIONS

During the determination of total zinc and metallic zinc in zinc powder, the test results are affected by various factors. The main factors affecting the test results and suggestions are summarized as follows.

1. Weighing of zinc powder samples. When weighing zinc powder, the subtraction method should be used. If the zinc powder is directly weighed using weighing paper or a weighing bottle, the zinc powder will stick to the weighing paper or the weighing bottle, resulting in a lower actual weighing mass, thus causing the test results of total zinc and metallic zinc to be lower.

2. Sample dissolution process. During the determination of total zinc and metallic zinc, the samples must be completely dissolved. If the samples are not fully dissolved, the measured total zinc and metallic zinc will be lower. During the dissolution process, low-temperature heating or ultrasonic waves can be used to fully dissolve the samples.

3. Reagents and instruments. All kinds of solutions, indicators, standard solutions, etc. used in the test process should be prepared using reagents of analytical grade or above, and blank experiments should be carried out according to the standard requirements to eliminate the influence of the reagents used; the preparation of standard solutions directly affects the accuracy of the measurement results. The Na_2EDTA standard titration solution required for the determination of total zinc and the $KMnO_4$ standard titration solution required for the determination of metallic zinc both require accurate weighing of the reference substances and precise calibration

according to the standard. During the calibration process, the purity, drying degree, weighing accuracy, etc. of the reference substances (such as zinc oxide) will affect the concentration of the standard solution. If it is difficult to prepare the standard solution in the laboratory, corresponding certified reference materials can be purchased for use; the measuring instruments such as analytical balances and burettes used in the test process should be regularly calibrated. If the analytical balance is not calibrated on schedule, weighing errors will affect the result calculation, and if the burette is not calibrated or leaks, the added amount of the standard titration solution will deviate.

(4) Titration operation process. The judgment error at the titration end point is the main source of operation error. The premature or delayed judgment of the titration color change point by the operator during titration will cause deviation in the titration volume. At the same time, the titration speed during the titration process will also affect the accuracy of the titration result. If the titration is too fast, it is easy to over-titrate. In addition, the lack of vigorous shaking of the conical flask during the titration process will also make the solution uneven, and the titration solution and the test solution will not react sufficiently, resulting in the operator's delayed judgment of the titration end point and thus making the test result on the high side. Therefore, during titration, the volume of the titration solution required should be roughly calculated according to the ranges of the total zinc content and the metallic zinc content in the sample. During titration, the titration speed should be fast first and then slow, and the titration speed should be slowed down when approaching the titration end point. At the same time, the conical flask should be shaken vigorously to ensure sufficient reaction between the titration solution and the test solution.

(5) Influence of temperature. Temperature change will cause the change of solution volume, thus affecting the result of titration analysis. Therefore, temperature correction should be carried out during titration.

5. CONCLUSION

This proficiency testing provided a basis for evaluating the zinc content in zinc powder by chemical titration in laboratories, reflecting the technical levels of participating laboratories in this testing field. For the total zinc parameter, the satisfaction rate of results was 87.1%; for the metallic zinc parameter, the satisfaction rate of results was 90.3%, and the results of most participating laboratories were satisfactory. The judgment of the titration endpoint by testers was the main factor affecting the result accuracy. Laboratories that did not obtain satisfactory results should carefully find out the reasons for dissatisfaction and make improvements to ensure the accuracy and reliability of subsequent tests.

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