

Mathematical Statistical Analysis on Proficiency Testing of the Total Number of Bacteria

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Abstract: In the paper the Proficiency Testing of the total number of bacteria in 34 laboratories were Analyzed and Counted. Z-score number were determined by statistical method. The Z-score was a standardized value assigned to each result. The testing results of 34 participating laboratories were evaluated. 3 laboratories with a Z-score of greater than 3 were unqualified results; 2 laboratories with a Z-score of less than 3 and greater than 2 were suspicious results.

1. Introduction

Bacteria are ubiquitous in nature. The total number of bacteria in food refers to the total number of bacterial colonies per gram of food samples under certain conditions. The determination of the total number of bacteria is used to determine the degree of bacterial contamination and the sanitary quality of food. If the total number of bacteria in food is too high, it is easy to cause food poisoning. In order to evaluate the total bacterial colonies testing ability of food inspection laboratory, Dalian Technical Center held several times of nationwide total bacterial colonies Proficiency Testing every year. All the national food inspection laboratories can sign up for participation. The organizer distributed test samples, participating laboratories tested, and fed back the testing data to the organizer. The organizer summarized the testing data of all participating laboratories, and then statistically analyzed the data, and evaluated the testing ability of the participating laboratories. If the test data was within the specified range of the total number of bacteria, it was the qualified result; if the test data was beyond the specified range of the total number of bacteria, it was the unqualified result, and the unqualified laboratory need to be rectified.

In the Proficiency Testing work, the data analysis and statistics of the total bacterial colonies testing results were particularly important, which required certain mathematical analysis and statistical knowledge. The normal distribution, mean and standard deviation, minimum value and maximum value of the data need to be analyzed; The robust statistical analysis method was adopted, median value and normalized interquartile range were used instead of arithmetic average value and standard deviation as the evaluation of overall parameters of test results, and finally the Z-score was calculated to evaluate whether the test results of participating laboratories were qualified.

2. Method

2.1 Ability Assessment Method

According to the Cnas - Gl002: 2018 for Ability Evaluation Way is as Follows:

Expert meetings, directly by the advisory group or other qualified expert determine whether report results consistent with goals; Experts agree is a typical method of evaluating qualitative test results.

With the target of compliance, according to the method of performance index and the predetermined criteria such as operating level of the participants.

Z-score number were determined by statistical method, and its criteria shall be applicable to each score.

2.2 Statistical Analysis Methods

In robust statistical methods, the median value and normalized interquartile range were used instead of arithmetic average value and standard deviation, respectively, as the evaluation test results of overall parameters.

The median and normalized interquartile range method was a simple and robust statistical method. Using this method, the mean and standard deviation of the data were estimated, which were median (MED) and normalized interquartile range (niqr). The median and normalized interquartile range were measures of data concentration and dispersion, similar to the mean and standard deviation.

The median value needs to be calculated as the specified value. The median value was an estimate of the middle position of the distribution. For a set of data arranged from small to large, the data in the middle position was the median value. Half of the data was higher than it, and half of the data was lower than it. It was calculated from sorted (low to high) test results. If the number of results (n) was odd, the median value was a single central value; If n was even, the median value was the average of the two central values. When the test result was ranked as $x_{(1)} \leq x_{(2)} \leq \dots \leq x_{(n)}$, the median value can be expressed by formula (1).

$$\text{Median} = \begin{cases} x_{(k)}, & k = (n+1)/2 \text{ while } n \text{ is odd} \\ [x_{(k)} + x_{(k+1)}]/2, & k = n/2 \text{ while } n \text{ is even} \end{cases} \quad (1)$$

The normalized interquartile range need to be calculated as the standard deviation of the capability evaluation. The normalized interquartile range (NIQR) was the standardized difference between the upper and lower quartiles. The data in the lower quarter was the lower quartile (Q1), one quarter of the data in this group was lower than Q1, and three quarters was higher than Q1; the data in the upper quarter was the upper quartile (Q3), one quarter of the data in this group was higher than Q3, and three quarters were lower than Q3. NIQR was calculated by formula (2). The normalized interquartile range was equal to the interquartile range (IQR) multiplied by a factor of 0.7413. The interquartile range was the difference between the upper and lower quartiles.

$$NIQR = 0.7413 \times [Q(3) - Q(1)] \quad (2)$$

The robust CV value was the coefficient of variation used to compare the differences between different samples or tests and was calculated by formula (3).

$$CV = 100NIQR / \text{median} \quad (3)$$

2.3 Ability Evaluation of Statistics

This paper adopts the statistical method to determine the Z-score, used in laboratory capacity evaluation. Z-score by the ability to validate the specified value and evaluation standard deviation.

2.3.1 Ability Evaluation Was Calculated by the Statistic Z-Score

The Z-score was a standardized value assigned to each result, which was related to other results in the same group of results. The Z-score closed to 0 indicated that the result was consistent with the results obtained by other laboratories. The Z-score was calculated by formula (4).

$$z = \frac{x - \text{Median}}{NIQR} \quad (4)$$

In the formula:

x--the test results reported by the participating laboratory;

Median--specified value (median value);

NIQR--normalized interquartile range.

Z-Z-score

2.3.2 The Evaluation Principle of Z-Score Was as Follows:

- $|Z| \leq 2$ was a satisfactory result;
- $2 < |Z| < 3$ Was a Problematic (Suspicious) Result;
- $|Z| \geq 3$ was unsatisfactory result (outlier).

3. Result

Based on the above statistical method, I analyzed the test data, calculated the median value and normalized interquartile range, and calculated the Z-score of each participating laboratory according to formula (4). The testing results and Z-scores of 34 participating laboratories were shown in Table 1. In order to clearly show the results of each laboratory participating in the ability evaluation of the total number of bacteria colonies, I made a histogram of Z values in order of size, as shown in Figure 1. The abscissa of each column was the sample number of the laboratory, and the ordinate was the Z-score of the laboratory.

Table 1 Summary and Statistical Analysis of Bacterial Colonies Testing Results

Laboratory code	Sample number	Result value(unit:CFU/ml)	Z value	Laboratory code	Sample number	Result value(unit:CFU/ml)	Z value
001	L138	220	1.12	018	L235	34	-0.55
002	L276	100	0.41	019	L347	65	0.03
003	L127	60	-0.05	020	L378	13	-1.41
004	L309	5600	4.02	021	L982	25	-0.83
005	L937	26	-0.79	022	L515	33	-0.58
006	L239	50	-0.21	023	L113	10	-1.65
007	L907	4900	3.90	024	L193	43	-0.34
008	L528	41000	5.80	025	L961	84	0.26
009	L139	14	-1.35	026	L382	20	-1.03
010	L519	48	-0.24	027	L728	50	-0.21
011	L579	240	1.20	028	L121	90	0.32
012	L983	140	0.71	029	L566	1500	2.84
013	L117	1500	2.84	030	L251	100	0.41
014	L329	150	0.78	031	L933	30	-0.67
015	L137	48	-0.24	032	L431	25	-0.83
016	L893	39	-0.43	033	L366	10	-1.65
017	L785	180	0.94	034	L345	339	1.51

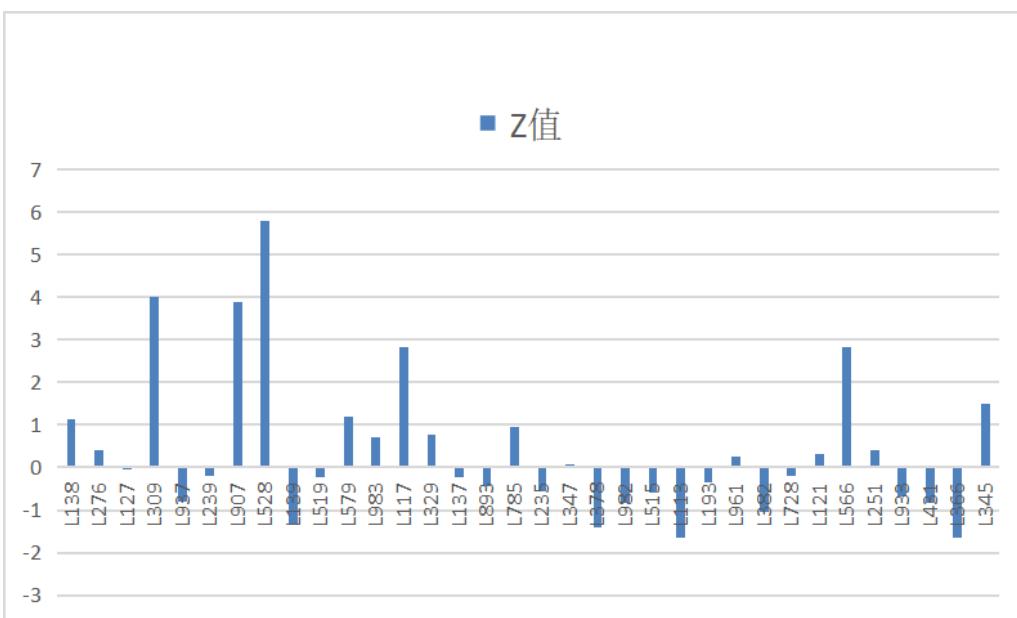


Fig.1 Histogram of the Testing Results of the Total Number of Bacteria

4. Conclusion

The summary and statistics of total number of bacteria test results by the participating laboratory. The testing results and Z-scores of 34 participating laboratories were shown in Table 1. The abscissa of each column was the sample number of the laboratory, and the ordinate was the Z-score of the laboratory. From the histogram, each laboratory was able to compare its results with those of other laboratories to understand the level of its results in this plan. According to the Z-score evaluation principle, the testing results of 34 participating laboratories were evaluated. 3 laboratories with a Z-score of greater than 3 were unqualified results, accounting for 8.82% of the participating laboratories; 2 laboratories with a Z-score of less than 3 and greater than 2 were suspicious results, accounting for 5.88% of the participating laboratories.

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