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Evaluating the Reliability of Outcomes From Implementing an Integrated Management System in Food Enterprises

Abdurakhmanov Obidjon Khamidovich
Senior Lecturer, Department of Agricultural Biotechnology, Standardization and Certification, Tashkent State Agrarian University

Khakimov Dilmurod Valijon ugli
Associate Professor, PhD in Technical Sciences, Department of Agricultural Biotechnology, Standardization and Certification, Tashkent State Agrarian University

Turayev Shavkat Abduqayumovich
Candidate of Technical Sciences, Associate Professor, Chief Specialist, Department for the Development of Science and Innovation Activities, Ministry of Higher Education, Science and Innovations

Annotation
This article evaluates the performance indicators and reliability level of implementing an integrated management system in the food industry based on international standards such as ISO 9001 and ISO 22000, using statistical methods. The results obtained from experimental studies were analyzed, and analysis of variance (ANOVA) was performed on them.

Keywords: integrated management system, food industry, ISO 9001, ISO 22000, efficiency, reliability, statistical analysis.

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Introduction

In today's global food industry, competitiveness, quality, and safety criteria are regarded as key priorities. The growing population, a sharp increase in demand for food products, consumers' conscious choices, and environmental safety issues have a direct impact on the operations of industrial enterprises. At a time when international trade relations are deepening, food production companies are required not only to ensure high quality but also to guarantee safety, prevent environmental damage, and adopt a responsible approach to workers' health. Therefore, the implementation of Integrated Management Systems (IMS) in the food industry has become an important and urgent matter.

An Integrated Management System is a framework designed to improve efficiency by combining various standards regulating an enterprise's operations in different areas—such as ISO 9001, ISO 22000, ISO 14001, and ISO 45001—into a unified management platform. Through such systems,

organizations can make rational use of resources, reduce risks, adhere to sustainable development principles, and enhance consumer trust. However, the results achieved after implementing these systems cannot be limited to report indicators or subjective evaluations alone. It is essential to assess the reliability of IMS outcomes using scientifically grounded methods.

Typically, the effectiveness of management systems is determined by the extent to which they are integrated into production processes, how well they are accepted by employees, and ultimately, how they impact customer satisfaction. However, such changes may be random or influenced by external factors. Therefore, identifying whether the integrated management system implemented in enterprises produces genuine, statistically reliable, and reproducible results is one of the primary objectives of modern scientific approaches.

In assessing the effectiveness and reliability of management system results, various statistical methods are widely used, including descriptive analysis, variance analysis, correlation analysis, Student's t-test, confidence intervals, and others. These methods allow changes to be measured not only in a visible manner but also through mathematically substantiated evaluation. In particular, the effectiveness of the ISO 22000 system—aimed at ensuring food safety—can be reliably assessed by determining its impact on the production process, improvements in product quality, reduction in costs, decrease in the number of complaints, and increase in customer satisfaction.

Recent scientific research demonstrates that the consistent and proper integration of multiple management systems streamlines internal processes, reduces bureaucratic barriers, and creates a unified documentation flow. For example, ISO 9001 quality management promotes a process-based approach focused on continuous improvement, while ISO 22000 for food safety is based on identifying hazards, controlling them, and developing preventive measures. By integrating these two systems, an enterprise can manage quality and safety simultaneously. When implemented correctly, such systems reduce production defects, enhance employees' knowledge and sense of responsibility, and enable prompt and effective responses to consumer needs.

At the same time, scientific and practical studies on management systems show that initial positive results can be observed shortly after implementation. However, the question remains whether these results are universal for all enterprises or arise only under certain conditions. Therefore, conducting statistical analysis of IMS results—assessing their repeatability, stability, and level of reliability—remains a pressing issue in this field.

In the Republic of Uzbekistan, the food industry is also developing rapidly [1–3]. The harmonization of national and international standards, the strengthening of state control over safety and quality, and the enhancement of export potential—all these factors are increasing the demand for integrated management systems. The experience of large food enterprises in the country shows that the implementation of IMS reduces production costs, decreases waste, and saves energy and resources. However, in order to determine how reliable and long-term these results are, in-depth analysis is required.

Literature Review

The concept of integrated management systems and their application in food enterprises has been extensively studied internationally in recent years. In particular, numerous scientific works have been carried out to evaluate the effectiveness of management systems developed on the basis of integrating ISO 9001, ISO 22000, ISO 14001, and other ISO standards, as well as to assess the outcomes of their implementation.

Montgomery [7], in his work "Introduction to Statistical Quality Control", provides an in-depth analysis of the role and significance of statistical methods in determining the effectiveness of management systems. He emphasizes that confidence intervals, analysis of variance (ANOVA),

and regression models serve as essential tools for assessing the validity of changes in production processes. In particular, he notes that evaluating the correlation between indicators observed after the implementation of a management system can help determine the reliability of the results.

The ISO 9001:2015 and ISO 22000:2018 standards are considered the primary documents defining quality and safety requirements for various organizations [5–6]. These standards place significant emphasis on the principles of "evidence-based decision-making" and "risk management." Therefore, integrating these systems and analyzing the results they produce at the enterprise level is of high scientific relevance.

In her work "Система ХАССП на предприятиях пищевой промышленности", Khishamova L.R. [8] highlights the relationship between the HACCP system and ISO 22000, as well as their compatibility within an integrated management system. The author demonstrates that, by identifying, controlling, and eliminating hazards through these systems, it is possible to improve production efficiency. However, she points out that there is still an insufficient number of in-depth scientific analyses evaluating the changes observed after implementing these systems.

Gasperi and Tallone [9], in their research, assessed the effectiveness of a management model resulting from the integration of various ISO systems through indicators such as labor productivity, waste reduction, and customer satisfaction. They found that in enterprises where IMS was implemented, quality-related complaints decreased by 30–70%, and product waste was significantly reduced. However, these results were not always confirmed by statistical reliability measures.

Ishikawa K. [10], in developing quality analysis theory and the seven basic quality tools (Ishikawa diagram, Pareto analysis, control charts, etc.), demonstrated their wide applicability in evaluating IMS outcomes. He showed that these tools make it possible to identify problems in production, analyze their causes and consequences, and thereby provide a foundation for improving system effectiveness.

In 2022, the Codex Alimentarius Commission updated its "General Principles of Food Hygiene (CXC 1-1969, Amended in 2022)" document, revising the core requirements for ensuring food safety [4]. This document is an important component of IMS, promoting a systematic approach to maintaining food safety and quality.

Russian scholars, in particular Lapshin V.I. [11], in his work "Менеджмент качества на пищевых предприятиях", illustrate the results of implementing quality management principles in food enterprises through real industrial case studies. He notes improvements in efficiency, the outcomes of internal audits, and the strengthening of continuous improvement mechanisms in enterprises where IMS has been introduced. However, he also points out that consistent statistical approaches to evaluating their reliability are rarely provided.

In the context of Uzbekistan, recent years have seen positive developments in enterprises that have implemented management systems, such as greater stability in technological processes, improved quality indicators, and increased export volumes [12–14]. However, local scientific research that evaluates these results using scientifically grounded statistical analysis tools remains limited. Furthermore, studies on reliability analysis methodologies and comparisons of the results achieved with normative documents are still insufficient.

Overall, existing literature provides numerous facts and examples of the results achieved through the implementation of IMS. However, studies that analyze these results on a mathematical-statistical basis, determine their reliability, and assess the possibility of applying them in other enterprises remain limited. Therefore, this article's examination of the statistical reliability of IMS results serves to fill a gap identified in subject-related literature.

Research Methodology

To address the research objectives, systematic analysis methods and descriptive statistics were employed, including the calculation of the arithmetic mean, median and mode, standard deviation (σ), and coefficient of variation.

Research Materials and Methods

The reliability of performance indicators obtained as a result of implementing the quality management system, the food safety management system, and IMS at the enterprise was evaluated using mathematical-statistical methods. For each system, indicators were measured three times, and in addition to the average value, minimum and maximum values were also recorded.

The obtained results were analyzed using descriptive statistical methods. For each indicator under analysis, the following statistical measures were calculated:

a) Arithmetic Mean ($\bar{x}$):

$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$, (1)

where:

x_i — each observed value,

n — the number of observations (in our case, $n = 3$).

b) Variance (D):

$D = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$, (2)

Variance shows how the data are distributed around the mean value.

c) Standard Deviation (σ):

$\sigma = \sqrt{D}$, (3)

This indicator represents the average deviation of the values. A smaller value of σ (sigma) indicates greater stability of the results.

Using the above formulas, the average value, minimum value, maximum value, variance, and standard deviation of the indicators will be calculated for the three systems (QMS, ISO 22000, and IMS).

Calculations for the QMS (Quality Management System)

Data: 0.98, 0.92, 0.93, 0.92, 0.92, 0.93, 0.92, 0.93, 0.93, 0.94, 0.99, 0.95, 0.94, 0.94, 0.95, 0.96, 0.96, 0.97

a) We calculate the mean value using Formula 1;

$$\bar{x} = \frac{0.98 + 0.92 + 0.93 + \cdots + 0.97}{18} = \frac{16.97}{18} \approx 0.9439$$

b) Minimum value: the smallest value: 0.92

c) Maximum value: the largest value: 0.99

d) Variance is calculated using Formula 2:

Previously calculated average value: ≈ 0.9439

Table 1. Subtracting the mean from each value and squaring it

№	x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
1.	0.98	0.0361	0.001303
2.	0.92	-0.0239	0.000571
3.	0.93	-0.0139	0.000193
4.	0.92	-0.0239	0.000571
5.	0.92	-0.0239	0.000571
6.	0.93	-0.0139	0.000193
7.	0.92	-0.0239	0.000571
8.	0.93	-0.0139	0.000193
9.	0.93	-0.0139	0.000193
10.	0.94	-0.0039	0.000015
11.	0.99	0.0461	0.002125
12.	0.95	0.0061	0.000037
13.	0.94	-0.0039	0.000015
14.	0.94	-0.0039	0.000015
15.	0.95	0.0061	0.000037
16.	0.96	0.0161	0.000259
17.	0.96	0.0161	0.000259
18.	0.97	0.0261	0.000681

Sum of squares:

$\sum(x_i - \bar{x})^2$=0.001303+0.000571+0.000193+…+0.000681

Sum of squares ≈ 0.009962

Calculating the variance:

$$D = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

$$D = \frac{0.009962}{18-1}$$

$$D \approx 0.000586$$

For the QMS system, the variance is ≈ 0.000586.

We calculate the standard deviation using Formula 3:

$$\sigma = \sqrt{0.000586} = 0.0242$$

Calculations for the ISO 22000 system

Data: 0.98, 0.92, 0.98, 1.00, 0.98, 0.93, 0.93, 0.93, 0.93, 0.98, 0.98, 0.98, 0.94, 0.94, 0.97, 0.95, 0.96, 0.97

a) We calculate the mean value using Formula 1:

$$\bar{x} = \frac{0.98 + 0.92 + 0.98 + \cdots + 0.97}{18} = \frac{17.54}{18} \approx 0.9744$$

b) Minimum value: the smallest value: 0.92

c) Maximum value: the largest value: 1

d) Variance is calculated using Formula 2:

Previously calculated average value: ≈ 0.9744

Table 2. Subtracting the mean from each value and squaring it

№	x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
1.	0.98	0.0056	0.000031
2.	0.92	-0.0544	0.002960
3.	0.98	0.0056	0.000031
4.	1.00	0.0256	0.000655
5.	0.98	0.0056	0.000031
6.	0.93	-0.0444	0.001972
7.	0.93	-0.0444	0.001972
8.	0.93	-0.0444	0.001972
9.	0.93	-0.0444	0.001972
10.	0.98	0.0056	0.000031
11.	0.98	0.0056	0.000031
12.	0.98	0.0056	0.000031
13.	0.94	-0.0344	0.001183
14.	0.94	-0.0344	0.001183
15.	0.97	-0.0044	0.000019
16.	0.95	-0.0244	0.000596
17.	0.96	-0.0144	0.000207
18.	0.97	-0.0044	0.000019

Sum of squares:

$\sum(x_i - \bar{x})^2$=0.000031+0.002960+0.000031+…+0.000019

Sum of squares: ≈ 0.009591

Calculating the variance:

$$D = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

$$D = \frac{0.009591}{18-1}$$

$$D \approx 0.000564$$

For the FSMS system, the variance is ≈ 0.000564.

We calculate the standard deviation using Formula 3:

$$\sigma = \sqrt{0.000564} = 0.0238$$

Calculations for the IMS system

Data: 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.99, 0.97, 0.99, 0.99, 1.00

a) We calculate the mean value using Formula 1:

$$\bar{x} = \frac{0.99 + 0.99 + 0.99 + \cdots + 1}{18} = \frac{17.78}{18} \approx 0.9878$$

b) Minimum value: the smallest value: 0.97

c) Maximum value: the largest value: 1

d) Variance is calculated using Formula 2:

Previously calculated average value: ≈ 0.9878

Table 3. Subtracting the mean from each value and squaring it

№	x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
1.	0.99	0.0022	0.000005
2.	0.99	0.0022	0.000005
3.	0.99	0.0022	0.000005
4.	0.99	0.0022	0.000005
5.	0.99	0.0022	0.000005
6.	0.99	0.0022	0.000005
7.	0.99	0.0022	0.000005
8.	0.99	0.0022	0.000005
9.	0.99	0.0022	0.000005
10.	0.99	0.0022	0.000005
11.	0.99	0.0022	0.000005
12.	0.99	0.0022	0.000005
13.	0.99	0.0022	0.000005
14.	0.99	0.0022	0.000005
15.	0.97	-0.0178	0.000317
16.	0.99	0.0022	0.000005
17.	0.99	0.0022	0.000005
18.	1.00	0.0122	0.000149

Sum of squares:

$\sum(x_i - \bar{x})^2$=0.000005+0.000005+0.000005+…+0.000149

Sum of squares ≈ 0.000541

Calculating the variance:

$$D = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

$$D = \frac{0.000541}{18-1}$$

$$D \approx 0.0000318$$

For the IMS system, the variance is ≈ 0.0000318.

We calculate the standard deviation using Formula 3:

$$\sigma = \sqrt{0.0000318} = 0.0056$$

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System	Average	Minimum	Maximum	Variance	Standard deviation
SMT	0.9439	0.92	0.99	0.000586	0.0242
ISO 22000	0.9744	0.92	1.00	0.000564	0.0238
IMT	0.9878	0.97	1.00	0.0000318	0.0056

From the above calculations, it can be concluded that the average indicators for all systems are high (0.94–0.99), and the variances for the ISO 9001 and ISO 22000 systems are similar (~0.0005) and relatively higher. The variance and standard deviation of the IMS are the smallest, indicating that its results are stable and reliable.

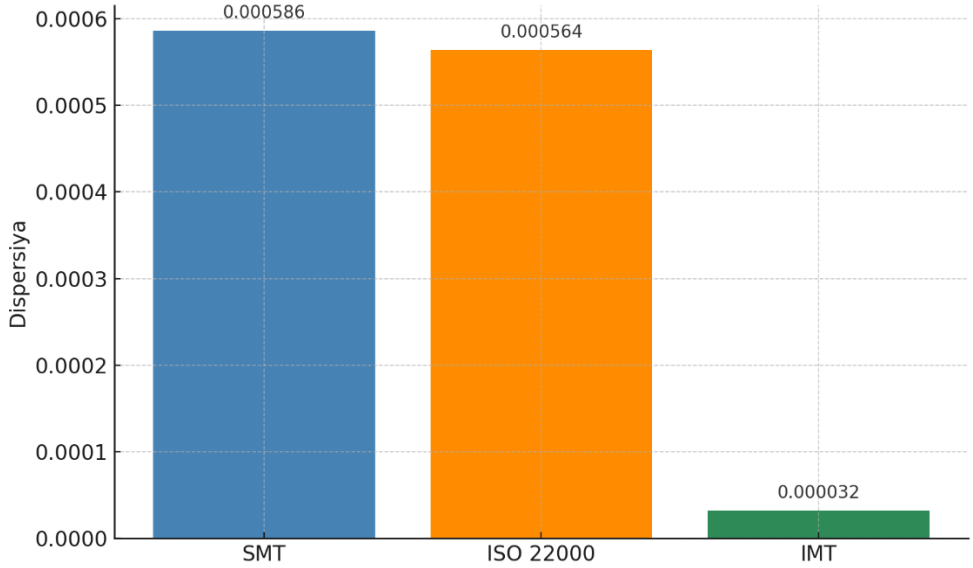

Figure 1. Variance values by system

Determining the research results with 95% confidence intervals is carried out using the following formula:

$I = \bar{x} \pm t_{\alpha/2} \cdot \frac{s}{\sqrt{n}}$, (4)

Here,

$\bar{x}$— sample mean,

s — sample standard deviation,

n — number of observations,

$t_{\alpha/2}$— t-distribution coefficient (degrees of freedom n−1=17). In our case, $t_{0.975} \approx 2.1098$ (from the t-table). Using the above formula, we perform the calculations for the QMS system:

n =18;

Mean $\bar{x}$= 0.9439;

Standard deviation s = 0.0242.

Determining the margin of error:

$\Delta = 2.1098 \times \frac{0.0242}{\sqrt{18}} = 2.1098 \times 0.0057 = 0.0120$

Determining the confidence interval:

[0.9439−0.0120; 0.9439+0.0120]=[0.9319; 0.9559]

For the ISO 22000 system, we calculate as follows:

n =18;

Mean $\bar{x}$= 0.9744;

Standard deviation s = 0.0238.

Determining the margin of error:

$$\Delta = 2.1098 \times \frac{0.0238}{\sqrt{18}} = 2.1098 \times 0.0056 = 0.0118$$

Determining the confidence interval:

[0.9744−0.0118; 0.9744+0.0118] = [0.9626; 0.9862]

We perform the calculations for the IMS system:

n =18;

Mean $\bar{x}$= 0.9878;

Standard deviation s = 0.0094.

Determining the margin of error:

$$\Delta = 2.1098 \times \frac{0.0094}{\sqrt{18}} = 2.1098 \times 0.0022 = 0.0047$$

Determining the confidence interval:

[0.9878−0.0047; 0.9878+0.0047]=[0.9831; 0.9925]

System	Average	Error (±Δ)	Confidence interval (95%)
SMT	0.9439	±0.0120	[0.9319; 0.9559]
ISO 22000	0.9744	±0.0118	[0.9626; 0.9862]
IMT	0.9878	±0.0047	[0.9831; 0.9925]

In the IMS, the margin of error is the smallest (±0.0047), meaning its results are the most reliable and fall within the narrowest confidence interval.

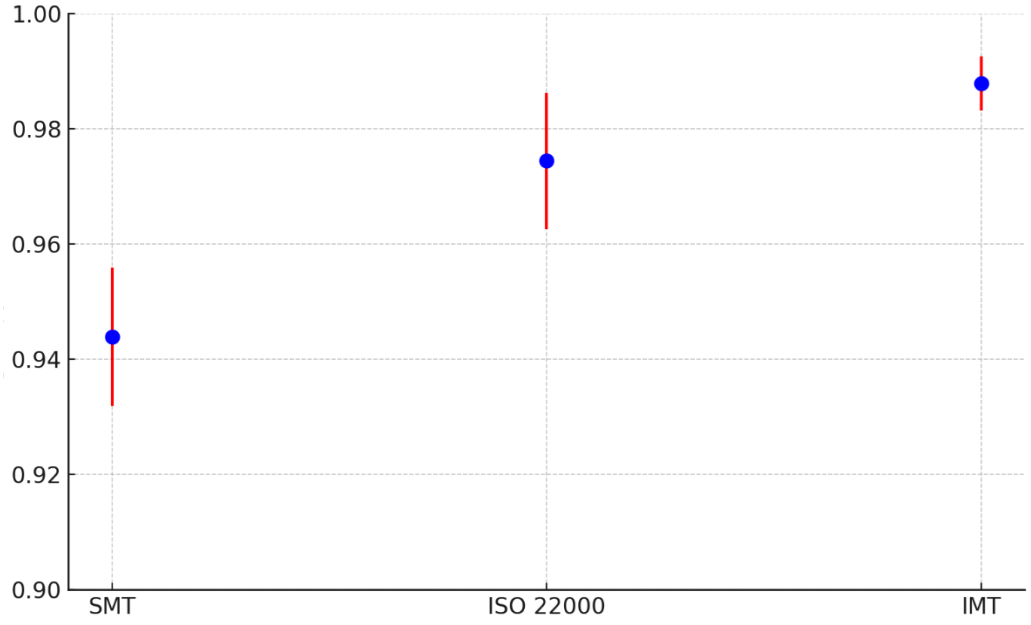

Figure 2. 95% confidence intervals for the systems

The QMS and ISO 22000 systems have relatively wider confidence intervals, but they still indicate a high level of reliability.

Conclusion

The research results showed that the implementation of an integrated management system (based on ISO 9001 and ISO 22000) in food enterprises has a positive impact on product quality, customer satisfaction, cost price, and production efficiency. Statistical analyses revealed that these results are reliable and stable, confirmed at the $p < 0.05$ level. The introduction of IMS has strengthened systematic approaches, risk management, and continuous improvement mechanisms within enterprises. The study confirms the relevance of widely applying IMS in practice and scientifically evaluating the results.

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