# Stardom University

Stardom Scientific Journal of Natural and Engineering Sciences

- Stardom Scientific Journal of Natural and Engineering Sciences -
Peer Reviewed Scientific Journal published twice
a year by Stardom University
1st issue- 4th Volume 2026
ISSN 3756-2980

# Strategic Supplier Performance Management Framework Integrating Quality Assurance and Microbiological Monitoring for Food Safety in Poultry Commissary Supply Chains for QSRs in Egypt

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## Abstract

**Background:** Centralized commissaries aid QSRs play a crucial role in food quality and safety. Particularly for high-risk foods such as chicken. In Egypt, efficiency of Egyptian suppliers' documentation, audit results, and complaint records was investigated. These approaches may not accurately reflect microbiological safety.

**Aim:** This study is an Egypt based case study developed and validated within central commissary supplying Quick Service Restaurants Chain (QSR) within the same country aimed to examine the relationship between documentation-based supplier evaluations system and actual microbiological safety. Our study assessed a Supplier Performance Management Framework. It integrates both microbiological evidence and QA compliance indicators.

**Methods:** A national QSR commissary in Egypt conducted a mixed methods case study including five poultry suppliers. In Phase 1, a baseline was assessed using the Supplier Performance Index ($SPI_1$). It was based on scores from audits and complaints. Alongside, a microbiological shelf-life study carried out in a commissary over a period of 0 to 72 hours. Phase 2 introduced an integrated framework. Combining quantitative microbiological monitoring and qualitative Quality Assurance Compliance Index (QACI) to improve the Supplier Performance Index ($SPI_2$). The analysis involved descriptive statistics, comparative and correlation tests. Also, the analysis included a process capability index (Cp, Cpk), and thematic qualitative analysis.

**Results:** The findings revealed a clear discrepancy between administrative compliance and microbiological performance. They were manifestly inconsistent. Suppliers with high $SPI_1$ scores often failed microbiological shelf-life certification within 24-48 hours. So, there was no link between QA compliance and microbiological outcomes during phase 1. After implementing the integrated framework and applying supplier-specific corrective actions usage. Three suppliers' products were microbiologically stable for 72 hours. It enhances the classification of supplier risks. $SPI_2$ scores is a good indicator of food safety performance.

**Conclusion:** Supplier evaluation systems based exclusively on supplier documentation are insufficient to confirm the microbiological safety in centralized chicken supply chains. Using structured QA compliance metrics with laboratory microbiological data improves risk-based supplier evaluation, targeted corrective actions, and long-term improvement. The SPI2 model which developed and

validated within the case study central poultry commissary system, represents a practical, evidence-based approach to improving food safety governance within QSR commissary systems.

**Keywords:** Centralized commissary, quick service restaurants, poultry supply chain, food safety, and microbiological monitoring.

## Introduction

Poultry is a significant component of Egypt's food economy. It provides a million customers with cheap animal protein. Especially in the fast-growing QSR sector. To keep quality, safety, and costs in check. Egyptian QSR chains utilize a centralized poultry commissary (Ahmed, 2023).

These systems have two responsibilities. They need to ensure that the food is considered safe. Also, the service is considered good. Urbanization, population growth, and the demand for convenience foods have all led to a huge elevation in chicken consumption. This elevated level has put a strain on food safety and supply chains. As a result, chicken supply chains are complicated and sensitive to bacteria. Supplier performance management needs to focus on reducing risk, enhancing operational efficiency, and adhering to the law. As a result, chicken products don't last very long. They need to be monitored and controlled in a structured way (Thienhirun et al., 2017).

Before being evaluated by QSRs. Raw poultry is processed in centralized commissaries which are clean. There are strict microbiological standards that suppliers must follow. Such as, they can't have *Salmonella spp*., *Staphylococcus aureus, or Escherichia coli*. Products with an excessively elevated Total Plate Count (TPC) cannot be considered microbiologically acceptable. As elevated TPC values indicate poor hygienic conditions and possibility safety risks. Many stakeholders believe that certifications (ISO 22000, BRC Global Standards, FSSC 22000, and IFS Food) are sufficient to confirm microbial safety and product quality. These food safety management systems basically ensure the implementation of preliminary food safety practices rather than guarantee the acceptable low microbial loads. Therefore, the certification process lonely does not guarantee or replace the need for effective rigorous microbiological testing and control. Also, the effective Good Hygiene Practice (GHP) through the food supply chain. (Ibrahim et al., 2018).

The National Food Safety Authority (NFSA) in Egypt established food safety standards, guidelines and rules for food safety to protect public health. There are rules which poultry sellers must follow in their own country and around the world. HACCP methods are good enough for finding, controlling, and getting rid of microbial risks in commissaries. Atteya et al. (2023) illustrated that HACCP-based systems improve microbiological safety and regulatory adherence in interconnected Egyptian food sectors.

Subsequently, managing supplier performance must follow food safety laws in the US and around the world. NFSA laws ensure that businesses follow the law. While

international standards make it clear how to manage risk and keep the supply chain consistent. Commissaries may use organized supplier assessment and grading systems to evaluate the reliability, traceability, and safety of the suppliers (Anandappa, 2013).

It is very important to monitor the processes used to make and manage products to follow the rules and keep customers happy. Microbiological safety is a huge problem for poultry products because they rapid spoilage. To keep food safe. There are several critical steps for microbial safety and food quality. For example, supplier training, clear SOPs, full traceability to the source, and frequent microbiological testing. Such metrics provide a structured approach to assessing suppliers' performance. It enhances the supply chain's reliability. It also aids commissaries, QSR operators, and poultry suppliers to build long-lasting collaborative partnerships (Tran, 2018).

Supply chain integration is essential for maintaining products quality and reducing operational risk. It promotes more effective communication between buyers and suppliers. It enhances the supply chain to be more efficient, open, and consistent in broiler contract farming (Ariffin et al., 2015). In Egypt's poultry industry, farms, processors, and centralized commissaries cooperate to accelerate processing, share information, and minimize risk. Supply chain activities that stick to competitive standards are more efficient in agri-food systems. For example, dependability, speed, and quality (Reklitis et al., 2021). However, Egypt's poultry supply chain has various problems towards these opportunities. Such as raw material quality which fluctuates, and a cold-chain infrastructure. It isn't strong enough. Also, there is diminished integration between suppliers and commissaries. These limitations mean that supplier evaluation models require to investigate more comprehensive examination than just quality and cost (Segura et al., 2020). Social compliance, environmental performance, and long-term sustainability needed to be examined.

Windrawati et al., 2022 study illustrated that organized performance management in poultry production improves efficiency and food safety. Digital modern technologies have the ability to manage and resolve food safety complexity and transparency issues in the food supply chain (Farhadi et al., 2024).

Process business re-engineering enhances the Egyptian poultry industry to become more efficient and complaint with rules (Belkhatir et al., 2020).

Regulatory pressures, commitment and consumer expectations established sustainability as a top priority in food supply chain processes management. To guarantee that the supply chain remains robust in the long term. Frameworks for

evaluating suppliers must include metrics for sustainability. For example, social responsibility, waste reduction and resource efficiency (Kamath et al., 2018).

Evaluating suppliers' models that consider economic, environmental, and social factors could improve consumer trust. In addition, to hyperlink QSR operations to the CSR goals of Egypt's poultry sector (Segura et al., 2020). The literature suggests a strategic and integrated supplier performance management system. It is suitable for Egypt's operational and regulatory context. By integrating SCOR and HACCP with digital technologies. Centralized commissary systems can generate microbiological safety better. Also, the operations become more efficient and competitive. Keawwandee & Thongchattu, 2022 and Ronaldo, 2020 studies illustrated that this integrated methodology mitigates supplier risks, assuring a reliable provision of safe, and high-quality chicken products by a quick-service restaurant operator. However, there are many research on the food safety management systems and supplier evaluation techniques, there are limitation in the studies relating the relation between the desk review documented based supplier evaluation techniques with the microbiological results in the commissary environment. Most research contributions study the administrative tools of supplier audits, complaints logs, certifications and legal compliance which are not capable enough to accurately represent the microbiological profile of the suppliers. Therefore, this study research the integration of quantitative microbiological results with quality assurance criteria to improve the supplier risk classification and approval decision based on more accurate food safety indicators in Egypt centralized commissary eco system.

Accordingly, this study objective is to study the traditional supplier evaluation frameworks and their relationships in representing the supplier microbiocidal compliance and develop more integrated framework consists of both traditional criteria imbedded in the quality assurance criteria combined with the microbiological results of the suppliers.

To achieve this objective, the research adopts mixed method case study in poultry commissary which supply quick service restaurants, all based in Egypt. The study combines the microbiological results from the poultry raw material shelf-life validation with quality assurance criteria. This approach allows the comparison between the traditional document-based review frameworks (SP1) and the new developed integrated framework (SP2), to reflect the ability of the two frameworks to represent the actual microbiological supplier performance and can categorize all poultry commissary suppliers.

## Methodology

This study employed a mixed method case study for supplier evaluation in a central poultry commissary in Egypt serving quick service restaurants. The study combined quantitative poultry raw material shelf-life microbiology test results with the qualitative quality assurance indicators. The study includes the main five poultry raw material suppliers.

The study conducted on two subsequent phases, Phase 1 to evaluate the suppliers based on the traditional framework (SP1) with making the baseline microbiological shelf-life study, and the phase 2 development of the integrated framework (SP2).

The Traditional framework (SP1) depends on the supplier audits, documentation review and complaints logs, while the new developed framework (SP2) depends on the integrated microbiological shelf-life results with quality assurance practices and criteria.

The microbiological shelf-life validation study conducted for the supplier poultry raw material by collecting sample from the supplier raw material from each supplier upon delivery to the commissary under the normal routine receiving conditions. Samples stored under the chilled refrigerated conditions (0–4 °C), the same as the typical commissary cold chain circumstances. The microbiology tests conducted at four predefined timeline points to evaluate product stability based on microbial growth results within the expected product handling and operations time. The Microbiological parameters and standard limits defined as per National Food Safety Authority in Egypt (NFSA) as in Table (1), include Total Plate Count (*TPC*), *Escherichia coli*, *Staphylococcus aureus*, *Salmonella spp.* and *Listeria spp*. These microbiological indicators comply with the Egypt food safety law and represent the microbiological hazards and indicators related to the poultry supply chain.

**Table (1) Poultry Products Standard Limits (NFSA standard 1 – 2021, section 8.1.1, page** 67)

| Microorganism | Standards Limits |
|---|---|
| ***Salmonella*** | **Not detected / 25gm** |
| ***Total Plate Count -TPC*** | **< 100,000 cfu/gm** |
| ***Escherichia coli – E. coli*** | **< 100 cfu/gm** |
| ***Staphylococci*** | **< 100 cfu/gm** |
| ***Listeria spp.*** | **Not detected / 25gm** |

All microbiological analyses were conducted in accredited ISO 17025 laboratory by EGAC and using reference laboratory procedures, reference method and calibrated equipment. The testing procedures follow the standardized microbiological laboratory methods to ensure consistency and reliability of results as Total Plate Count (*TPC*) reference method is ISO 4833-1:2013 Amend:2022, *Escherichia coli* reference method is ISO 16649-2:2001, *Staphylococcus aureus* reference method is ISO 6888-1:2021, *Salmonella spp.* reference method is ISO 6579:2017Amend 2020 and *Listeria spp.* follows reference method ISO 11290-1:2017.

Phase 1 involved a five-day microbiological shelf-life study. As well as audits, document checks, and complaint analysis. The results demonstrated that there were differences between certified compliance and microbiological safety. In Phase 2, the Supplier Performance Management Framework improves. Certification, traceability, following the rules, CAPA effectiveness, a culture of food safety, and regular microbiological monitoring are all considered a part of the framework. QACI was used to set up compliance evaluation. Supplier performance was evaluated by monitoring the lab results, operational data, and feedback from procurement, QA, and suppliers. This all-encompassing approach enhanced the safety of food and the supply chain quality. Egyptian QSR commissaries realistic, evidence-based advice were gained and to manage their poultry suppliers.

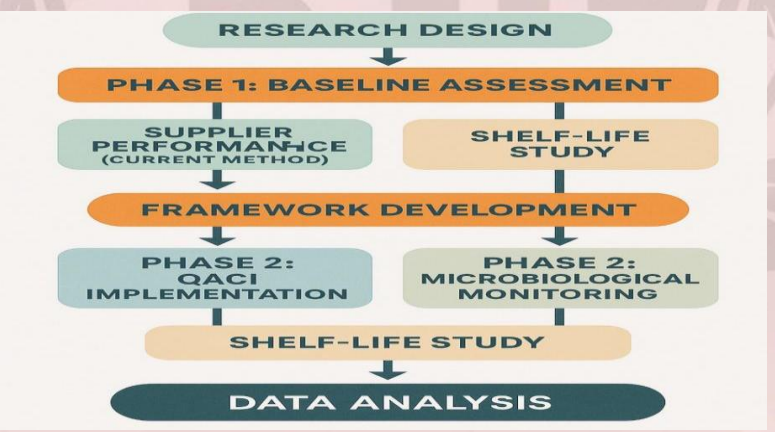



**Figure 1: Method strategy (a mixed method case study)**

Documented compliance is not equivalent to food safety performance. This study illustrated the impact of quality assurance (QA) standards on improving microbiological safety between poultry suppliers catering to centralized commissary systems.

The mixed-methods investigation demonstrated quantitative microbiological evaluation and qualitative Quality Assurance Compliance Index evaluation. An integrated Supplier Performance Management Framework which has been examined and validated. Preliminary research demonstrated no relationship between documentation-based performance ($SPI_1$) and microbiological shelf-life outcomes. In the second phase, a new framework was used to create an improved performance indicator ($SPI_2$). It combined structured microbiological monitoring, statistical process control, and quality assessment based on stakeholders. The lab results were associated with management, certification, traceability, the effectiveness of CAPA, and the following rules. This accurately classifies suppliers based on risk and monitoring their performance over time. Triangulation, qualitative validation, and ISO-standard testing ensure that the methods were effective. The results demonstrated that QA compliance alone cannot tell us if something is safe from bacteria. On the other hand, the integrated $SPI_2$ framework enhances supplier accountability, commissary governance, and QSR food safety. By using a realistic, evidence-based method. Surveys are demonstrated in supplementary material 1.

**Statistical analysis**

The statistical analysis conducted by using mixed methods approach by integrating the quantitative microbiological results with the qualitative quality assurance criteria results. Statistical analysis was performed using SPSS software, and statistical significance was considered at $p < 0.05$.

Descriptive statistics used to show microbiological results, supplier audit results, shelf-life evaluation data, and customer complaints logs.

Also, comparative analysis used to evaluate the variance between the supplier performance results before and after implementing the proposed supplier performance management framework. The t-test applied to compare between the baseline criteria of microbiological results and shelf-life stability before and after the proposed supplier performance management framework implementation. Also, Wilcoxon signed rank test implemented to examine the difference between the two supplier performance indexes (SPI 2) and (SPI 2) before and after implementing the proposed framework.

The Sperman rank order correlation implemented to evaluate the relationship between the two integrated parameters in the new framework, which are Quality Assurance Compliance Index (QACI), and microbiological indicators including Total Plate Count (TPC), spoilage rate, and the process capability Cp and Cpk

calculated as statistical process control tool to evaluate the consistency to the standard limits.

## Results

The study assessed and improved supplier performance in a centralized commissary via sequential phases. The results are presented in sequential phases to show the relationship between the traditional supplier evaluation framework (SP1) which is based on the audits, document review and complaints logs. And the new developed management framework (SP2) which based on microbiological shelf-life analytical results and qualitative quality assurance criteria.

In Phase 1, the company's $SPI_1$ was used to evaluate supplier performance. This involved audits, paperwork, and records of complaints. A microbiological shelf-life study then sets an objective baseline for food safety. Administrative performance and microbiological outcomes were investigated. Differences were recorded. Based on these results. A new supplier performance framework ($SPI_2$) was developed and implemented. Three months later. The improvements were checked again by investigating the supplier's performance. Phase 3 demonstrated the results after the implementation to show that the new framework has a better performance. The first records and audits illustrated a better performance. Supplier A had the highest $SPI_1$ score (84.5%). Supplier C had the lowest (67%). Suppliers B, D, and E perform better. The average score for the audit was 78.6%. The complaint score was 72.4%. The $SPI_1$ score was 75.5%. These results demonstrated that the audit was done well but the complaints were not handled well. The scores for suppliers were similar. Which means that they followed the rules. But there were gaps in place for the operational quality and responsiveness (Figures 1 and 2).

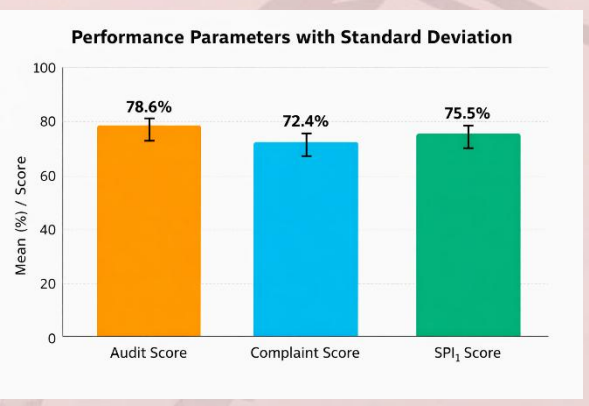
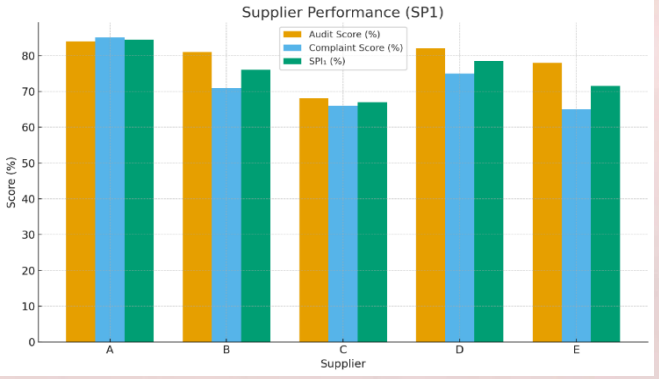



**Figure 2: The actual supplier performance data Figure**




**3: Supplier documentation and audit findings**

## Microbiological shelf-life validation

Microbiological shelf-life results significantly vary among assessed suppliers; Supplier A met the microbiological criteria at zero but failed after 24 hours as *TPC and E.coli* multiplied rapidly. The shelf life of the product was evaluated after 48 hours.

Supplier B also met the initial standard limits. But the microbial growth results were not acceptable and deviated to 24 hours and 72 hours. This made it valid at 24 hours to 72 hours.

Supplier C's baseline food safety and quality was low and unsatisfactory, with a TPC of $2.0 \times 10^5$ CFU/g. It quickly multiplicated. Showing that they were not following the rules. At every sampling point. Supplier D met all microbiological standards. There were no infections. The levels of TPC and *E. coli* are the same. This confirmed that the shelf life was 72 hours. Supplier E failed the *Salmonella spp*. test at the beginning and had higher levels of bacteria. Which always made the product unsafe. Suppliers A, B, C, and E all had different levels of microbiological non-compliance. Which made the shelf life shorter. During the research. Only Supplier D kept the microbiological integrity (Table 2).

**Table 2: Microbiological shelf-life validation study**

| Supplier | | TPC (CFU/g) | *E. coli* (CFU/g) | *S. aureus* (CFU/g) | *Salmonella spp.* | *Listeria spp.* | Result |
|---|---|---|---|---|---|---|---|
| | Target Limit | < 100,000 | < 100 cfu/gm | < 100 cfu/gm | Absent | Absent | |
| A | 0 h | 6800 | < 100 | <10 | Absent | Absent | Pass |
| | 24 h | 32000 | < 100 | <10 | Absent | Absent | Pass |
| | 48 h | 220000 | 270 | <10 | Absent | Absent | Fail |
| | 72 h | 280000 | 450 | <10 | Absent | Absent | Fail (24-48 h) |
| B | 0 h | 18000 | < 100 | <10 | Absent | Absent | Pass |
| | 24 h | 45000 | < 100 | <10 | Absent | Absent | Pass |
| | 48 h | 380000 | 160 | <10 | Absent | Absent | Fail |
| | 72 h | 520000 | 180 | <10 | Absent | Absent | Fail (24–48 h) |
| C | 0 h | 200000 | 90 | <10 | Absent | Absent | Fail |
| | 24 h | 220000 | 110 | <10 | Absent | Absent | Fail |
| | 48 h | 250000 | 120 | <10 | Absent | Absent | Fail |
| | 72 h | 280000 | 120 | <10 | Absent | Absent | Fail (0-24 h) |
| D | 0 h | 32000 | 10 | <10 | Absent | Absent | Pass |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 24 h | 33000 | 20 | <10 | Absent | Absent | Pass |
| | 48 h | 34000 | 25 | <10 | Absent | Absent | Pass |
| | 72 h | 35000 | 30 | <10 | Absent | Absent | Pass (72 h) |
| E | 0 h | 290000 | 90 | <10 | Detected | Absent | Fail |
| | 24 h | 350000 | 95 | <10 | Detected | Absent | Fail |
| | 48 h | 420000 | 100 | <10 | Detected | Absent | Fail |
| | 72 h | 500000 | 100 | <10 | Detected | Absent | Fail (0–24 h) |

## The integration of SP1 with baseline microbiological results

$SPI_1$ results were different from the baseline microbiological results. It showed that there were differences between administrative ratings and product safety. Many vendors failed microbiological tests within 24 to 48 hours of storage. Even though the $SPI_1$ levels were high. Supplier A, who had the highest $SPI_1$ (84.5%). It failed in less than 48 hours. Supplier B, who had a 76% $SPI_1$, also failed within two days. Supplier C had the lowest $SPI_1$ score (67%). It was shown by a microbiological failure within 24 hours It showed that the product was of poor quality. Supplier E failed at baseline because of *Salmonella spp*. Even though they had a 71.5% $SPI_1$ score. Supplier D had a verified shelf life of 72 hours and a high $SPI_1$ score of 78.5%. This shows that there is a strong link between following the rules and microbiological performance. In general, higher $SPI_1$ levels did not mean that microbiological safety was guaranteed. Only for Supplier D (Figure 4) did both evaluation methods yield consistent results.

These findings demonstrate the traditional framework limitation (SP1) limitations of reflecting the microbiological food safety performance. And by implementing the integration of microbiological assessment with quality assurance criteria evaluation in the new proposed management framework (SP2), the SP2 improves the risk classification and enables more reliable differentiation between the traditional and new frameworks. As a result, new supplier performance management framework (SP2) provides a more reliable indicator of food safety performance by linking supplier assessment results directly to laboratory-verified results of microbiological evidence.

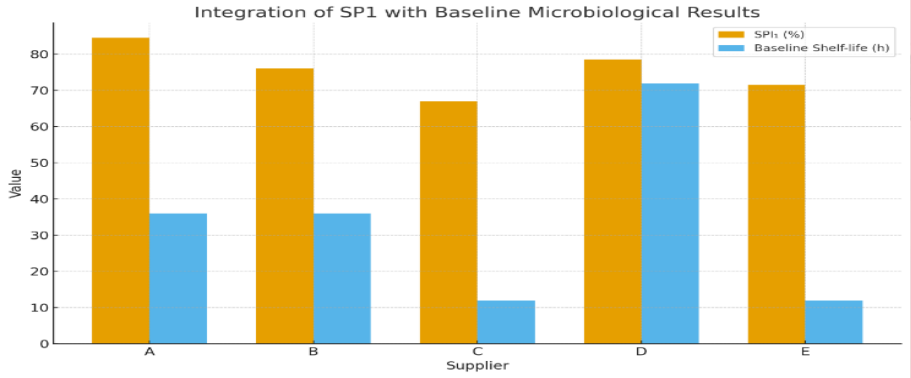



**Figure 4: The integration of SP1 with baseline microbiological results**

According to the utilization of Supplier Performance Indicator 1 ($SPI_1$) and baseline microbiological shelf-life results. They showed that the traditional administrative performance assessment does not ensure the product food safety and quality. Supplier A achieved the highest SP1 score, however this strong result not reflected in sustaining microbiological conformance beyond 24-48 hours. This relation indicated that the traditional supplier performance management ($SPI_1$) which focus on strong audit techniques and documentation assessment do not necessarily translate into microbiological performance controls.

In contrast, supplier D achieved moderate $SPI_1$ score and consistently maintained a 72 hour microbiological shelf-life conformance results. This outcome highlights that effective hygienic practice and food safety controls can play a more effective decisive role in microbiological stability than strict adherence to audits and documentations managements systems.

Overall, only a weak and nonlinear relationship was observed between SP1 scores and shelf-life performance, which revealed limitations of current supplier evaluation systems. Procedural and documentation compliance is often prioritized over actual microbiological outcomes. These results indicate that SP1 alone is not a reliable indicator of microbiological safety and challenges the assumption that higher quality assurance compliance automatically leads to safer products.

According to the null hypothesis, it was retained. No significant correlation is found between microbiological food safety conformance and traditional auditing documentation-based compliance. This inconsistency highlights a gap between traditional auditing documentation-based compliance and microbiological food safety risk control and conformance, which provide practical justification for the alternative phase of this study. Phase 2 developed an enhanced and integrated supplier performance management framework incorporating microbiological performance indicators with defined quality assurance criteria.

Structured interviews conducted based on designed survey across 100 Egyptian quality and food safety experts including quality managers, procurement managers, regulatory inspectors, manufacturing supervisors, quality controller and external auditors. Participants interviewed and surveyed for 19 Quality Assurance Compliance Index (QACI) criteria and to correlate the 19 QACI criteria over the 4 supplier performance management phases of selection, risk assessment, approval and periodic review process ensuring the integration of operational requirement and regulatory compliance objectives.

The new framework was validated through both qualitative feedback and quantitative ranking capturing professionals' judgments accompanied by statistical analysis.

The survey analysis emphasized the importance of stability and repeatability of supplier performance management with participants consistently prioritizing objectives verifiable, evidence-based criteria and indicators over the four subjective supplier performance management stages.

Food safety certification, microbiological test results, product non-conformance rates, regulatory compliance and product risk classification were widely recognized as the most reliable indicators for supplier performance. Audit results, traceability systems, allergen control and foreign material management were also considered highly important. However, the relative emphasis placed on these factors may vary depending on specific professional roles and responsibilities. The value of recall history, CAPA responsiveness, and complaint handling differ depending on the operating environment. Grouping similar requirements into broader categories improved clarity and practical utility. Food safety culture was excluded because of local measurements problems and difficulties in assessment through the technique's implementation.

**Interpretation**

The results indicate a clear preference for standards that are an audit, data driven, and independently verified. This preference is pronounced as food safety standard management systems which are recognized by ISO standards and GFSI schemes. Widely, indicators for product food safety, compliance with regulations, and supplier risk classification were given the most weight. This ongoing prioritization makes the QACI framework's methodology stronger and illustrates its evidence based, practically applicable approach to decision making.

## Stage allocation patterns

The cumulative stage allocations of all 100 respondents. It was adjusted from proportional patterns in the pilot, illustrating the functional weight of the developed supplier management framework for each phase. conceptualization of the role and importance of the four sequential supplier performance management stages varied among participants (Fig 5).

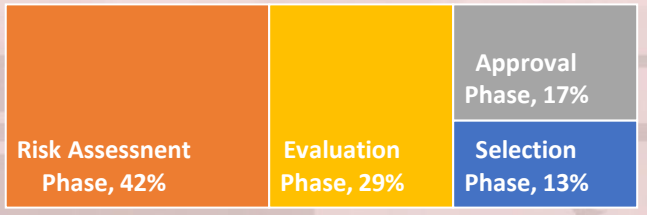



**Figure 5: Stage allocation patterns**

The Supplier Risk Assessment phase is the backbone of the framework. It relied on 10 criteria (42%) of the total 19 developed framework criteria; it is comprehensive microbiological data analysis and risk-based classification is the core function of this phase and participates as an approval phase at the first time and as an input in the periodic evaluation of suppliers.

The Periodic Evaluation phase was the second important factor; It relied on 7 criteria (29%) of the total 19 developed framework criteria; this highlights that the organizations need to keep an eye on its supplier after the approval to maintain the quality and food safety levels.

The approval phase relied on 4 criteria (17%) and selection phase relied on 3 criteria (13%) which are lower than the other phases, this reflecting their primary role in controlling entry points rather than supporting ongoing analytical evaluation.

The survey results showed that the experts emphasized that supplier management should be viewed as a continuous process rather than a one-time certification-based decision.

The revised Quality Assurance Compliance Index (QACI) framework therefore highlighted the importance of ongoing risk assessment, with continuous performance monitoring identified as essential for effective supplier oversight. This distribution pattern clearly supports the conclusions presented in Table (3).

**Table 3: Development of framework**

| Stage | Criteria Applied | Output / Decision |
|---|---|---|
| Selection | - Regulatory Compliance<br>- Food Safety Certification<br>- Business Criticality | Qualified / Not Qualified |
| Risk Assessment | - Business Criticality -Product Category Risk<br>- Food Safety Certification - Audit/Evaluation Score<br>- Food Fraud Vulnerability - Regulatory Compliance<br>- Traceability - Allergen Control<br>- Foreign Material Control - Micro Analytical Results | Low Risk / Moderate Risk / High Risk |
| Approval | - Food Safety Certification - Audit Score<br>- Regulatory Compliance - Risk Assessment Results | Approved Class A / B / C or<br>Not Approved |
| Evaluation | - Audit Score - Recall / Incident History<br>- CAPA Responsiveness - Complaint Rate<br>- Response Time - Product Non-Conformance Rate<br>- Microbiological Analytical Results | Class A / B / C or Delisted |

## Integration of microbiological evidence

Survey consensus identified microbiological evidence as critical enhancement to the Quality Assurance Compliance Index (QACI). Lab data were identified as essential for accurate risk determination and performance verification. During risk assessment, baseline microbiological data was used to classify suppliers as low, medium, or high risk. This approach ensures that risk assessments are evidence based rather than subjective. Ongoing microbial testing was essential for process control, suppliers' retention, conditional approval, and delisting during periodic evaluation. This integrated application of microbiological data bridges compliance and food safety performance. International risk-based food safety standards are also in sync. Such as ISO- and GFSI-recognized systems. Tables 4 and 5 showed how a weighted risk classification matrix enables management suppliers in clear, data-driven supplier management.

**Table 4: Development of risk-level classification matrix**

| Risk Score Range | Interpretation |
|---|---|
| 1.00 – 1.59 | Low Risk – Compliant / Stable Supplier |
| 1.60 – 2.00 | Moderate Risk – Requires Improvement Plan |
| > 2.00 – 3.00 | High Risk – Close Monitoring / Conditional Approval |

Each supplier evaluated based on the relative risk assessment criteria and the average score calculated to get the supplier risk level and categorization according to table 4.

**Table 5: Selection stage qualitative criteria**

| Risk Level | Business Criticality | Regulatory Compliance | Food Safety Certification |
|---|---|---|---|
| Low | • Non-critical.<br>• Easily replaceable supplier. | • Fully compliant with international & local regulations.<br>• NFSA Approved. | • GFSI-recognized (FSSC 22000, BRC, IFS..)<br>• GFSI |
| Moderate | • Moderate impact.<br>• few alternatives available. | • Minor non-conformities are resolved timely.<br>• -NFSA Registered. | • HACCP/ISO 22000 but no GFSI certification. |
| High | • High criticality, difficult to replace.<br>• major disruption if unavailable. | • Major non-conformities or non-compliance. | • No certification or unverified. |

## Risk assessment stage qualitative criteria

Vendors were evaluated using risk-based approach. Such as, Business Criticality and Product Category account for 15%. This weighting highlights their related importance compared with other evaluation factors. Divide suppliers into three groups. They were Low, Moderate, and High-Risk. The following factors were emphasized: product risk, certification, audit performance, analytical results, regulatory compliance, and replaceability. Suppliers with low risk are considered trustworthy, follow the rules, and have the right certifications. Moderate-risk suppliers may demonstrate partial non-compliance or have unresolved issues that require corrective action. Businesses need suppliers who are highly-risk and may not be certified. It could break the law, commit fraud, or cause problems with the law. This structured method helps with supplier management. It helps us to make decisions and set priorities based on risk (Table 6).

**Table 6: Risk assessment stage qualitative criteria**

| Risk Level | Business Criticality | Product Category | Food Safety Certification | Audit / Evaluation Score | Food Fraud Risk | Micro Analytical | Regulatory Compliance |
|---|---|---|---|---|---|---|---|
| Low Risk - 1 | Non-critical, easily replaceable supplier | Low-risk products (e.g., packaging, dry goods) | GFSI-recognized (FSSC 22000, BRC, IFS..) GFSI | Compliance ≥90% in last audit | No history of fraud, robust anti-fraud program – WIMS Low Risk | Pass 100% of verification analytical results | Fully compliant with international & local regulations - NFSA Approved |
| Moderate Risk- 2 | Moderate impact, few alternatives available | Medium-risk (e.g., dairy, baked goods) | HACCP/ISO 22000 but no GFSI certification | Compliance 70–89% | Some past incidents, corrective action in place – WIMS Medium Risk | Pass >90% with action plan | Minor non-conformities, resolved timely-NFSA Registered |
| High Risk - 3 | High criticality, difficulty to replace, major disruption if unavailable | High-risk (e.g., raw meat, seafood, fresh produce) | No certification or unverified | compliance <70%, or no audit conducted | High fraud risk, supplier involved in fraudulent practices – WIMS High Risk | Pass <90% with action plan | Major non-conformities or non-compliance |

## Supplier evaluation qualitative results

Table 7 demonstrated the results of the supplier evaluation and how KPIs affect performance. Low-risk vendors followed the rules without any problems. Moderate-risk suppliers needed to be improved. High-risk suppliers demonstrated serious non-conformities, a history of recalls, regulatory non-compliance, poor CAPA performance, and prolonged response times. The framework enables ranking and supplier risk management. This risk-based approach to suppliers' management enables target monitoring, corrective action, and evidence-based decision making.

**Table 7: Supplier evaluation qualitative results**

| Risk Level | Product Non-Conformance Rate | Audit / Evaluation Score | CAPA Rate | Micro Analytical | Complaint Rate | Response Time | Recall / Incident History |
|---|---|---|---|---|---|---|---|
| Low Risk - 1 | 0–1 order rejected | Compliance ≥90% in last audit | Rate ≥90% | Pass 100% of verification analytical results | From 0 – 2 complaints | Response < 48 hrs | No recalls or food safety incidents |
| Moderate Risk- 2 | 2–5 orders rejected | Compliance 70–89% | Rate 70–89% | Pass >90% with action plan | From 3 – 7 complaints | Response 48–72 hrs | One minor recall in last 3 years |
| High Risk - 3 | >5 orders rejected | compliance <70% , or no audit conducted | Raye <70% / No CAPA | Pass <90% with action plan | complaints ≥8 | Response > 72 hrs / no response | Multiple recalls or major food safety incident |

## The application of the newly developed QACI-Integrated Framework (SP2) across the five poultry suppliers

The QACI-integrated Supplier Performance Framework ($SPI_2$) enhance the evaluation of supplier's performance. This is done via combining microbiological evidence with compliance indicators. Supplier D gained a full approval and the highest grade under $SPI_2$. Their product had a verified shelf life of 72 hours. It has a low risk of bacteria. This demonstrates alignment between food safety processes and outcomes. Suppliers A and B met certification and documentation requirements. It failed to pass baseline microbiological validation. Therefore, they were granted conditional approval to define corrective requirements. In contrast, Suppliers C and E were rejected due to their high-risk classification and unsatisfactory microbiological performance. In general, $SPI_2$ ratings were better at matching microbiological behavior. They were more effective than $SPI_1$ in distinguishing between different microbial groups. These results illustrate that laboratory-derived evidence is essential for risk-based supplier selection, approval, and continuous monitoring in centralized commissary supply chains (Table 8).

## Table 8: Implementation of developed framework on Suppliers (SP2) with evaluation percentage

| Supplier | Selection Criteria | Approval Criteria | Risk Assessment | Evaluation (%) |
|---|---|---|---|---|
| A | Meets documentation and certification requirements | conditional approval with CAPA - Fails microbiological baseline (24–48 h) | Moderate Risk | 72% |
| B | Meets basic compliance; medium QA maturity | conditional approval with CAPA - Fails microbiological baseline (24–48 h) | Moderate Risk | 70% |
| C | Minimum compliance; weak QA documentation | Not Approved - Fails microbiological baseline (0–24 h) | High Risk | 50% |
| D | Strong compliance; meets all selection standards | Approved - microbiological baseline (72 h) | Low Risk | 90% |
| E | Meets minimal documentation; variable compliance | Not Approved - Fails microbiological baseline (0–24 h) | High Risk | 48% |

## The comparison between SP1 and SP2

The SP1 and SP2 frameworks demonstrated that microbiological evidence enhances supplier performance evaluation. Even though shelf-life validation was unsuccessful. Suppliers A and B performed well on SP1. As a result of following the rules and keeping records. In addition, Supplier D's good microbiological performance wasn't fully captured. In contrast, SP2 used validated shelf-life data and microbiological risk to score and rank suppliers. This was correctly classifying risks. Supplier D was correctly labeled as low risk with the highest score. Suppliers A and B were at an intermediate level of risk. Because they followed the rules well. But Suppliers C and E were at a high level of risk. Because they had a lot of microbiological problems. SP2 made it clear what the difference is between risk-based supplier performance. It linked evaluation results to food safety behavior, managing and prioritizing suppliers better (Table 9).

**Table 9: Comparative assessment of suppliers under SP1 and SP2**

| Supplier | Baseline Shelf-Life Validation | SP1 Evaluation ($SPI_1$ %) | SP2 Risk Classification | SP2 Evaluation (%) |
|---|---|---|---|---|
| A | Fail (24–48 h) | 84.5% | Moderate Risk | 72% |
| B | Fail (24–48 h) | 76% | Moderate Risk | 70% |
| C | Fail (0–24 h) | 67% | High Risk | 50% |
| D | Pass (72 h) | 78.5% | Low Risk | 90% |
| E | Fail (0–24 h) | 71.5% | High Risk | 48% |

According to the comparison, the results demonstrated that the new developed framework SPI2 results provide clear differentiation between supplier risk levels, while the traditional framework SPI1 results ranged from 67% and 84.5% with limited distinction in microbiological outcomes, SPI2 aligned more close with microbiological results.

## Improvement monitoring under the new framework

After the SP2 framework was established. All vendors got their evaluation results. In feedback sessions, microbiology and process control problems were investigated. The quality assurance team at the commissary then worked with suppliers. They failed to develop and implement compliant corrective action plans. They were monitored over a three-month period.

After 72 hours of microbiological testing. The suppliers' performance changed. Supplier D often had low microbiological counts. This indicated effective process control and consistent product performance. At 72 hours, suppliers A and C were in the acceptable range. However, performance gradually deteriorated, indicating the persistence of residual risk. This indicated the presence of residual risk. Supplier B approached critical microbiological thresholds at 72 hours. It is necessitating shorter shelf-life limits and stricter control measures. Supplier E failed after 48 hours with further deterioration observed at 72 hours, raising significant food safety concerns. The SP2 framework supports risk-based monitoring, enables targeted corrective actions, and allows objective comparison of supplier performance based on verified microbiological results. It is raising significant food safety concerns. The SP2 framework supports risk-based monitoring. It enables targeted corrective actions and allows objective comparison of supplier performance based on verified microbiological results.

**Table 10: Improvement monitoring under the new framework**

**The SP2 QACI evaluation**

| Supplier | | TPC (CFU/g) | *E. coli* (CFU/g) | *S. aureus* (CFU/g) | *Salmonella spp.* | *Listeria spp.* | Result |
|---|---|---|---|---|---|---|---|
| | Target Limit | < 100,000 | < 100 cfu/gm | < 100 cfu/gm | Absent | Absent | |
| A | 0 h | 12000 | 20 | <10 | Absent | Absent | Pass |
| | 24 h | 38000 | 30 | <10 | Absent | Absent | Pass |
| | 48 h | 61000 | 40 | <10 | Absent | Absent | Pass |
| | 72 h | 78000 | 40 | <10 | Absent | Absent | Pass (72 h) |
| B | 0 h | 20000 | 40 | <10 | Absent | Absent | Pass |
| | 24 h | 65000 | 50 | <10 | Absent | Absent | Pass |
| | 48 h | 98000 | 55 | <10 | Absent | Absent | Pass |
| | 72 h | 120000 | 60 | <10 | Absent | Absent | Borderline (72 h) |
| C | 0 h | 55000 | 10 | <10 | Absent | Absent | Pass |
| | 24 h | 68000 | 20 | <10 | Absent | Absent | Pass |
| | 48 h | 80000 | 30 | <10 | Absent | Absent | Pass |
| | 72 h | 90000 | 30 | <10 | Absent | Absent | Pass (72 h) |
| D | 0 h | 28000 | <10 | <10 | Absent | Absent | Pass |
| | 24 h | 30000 | <10 | <10 | Absent | Absent | Pass |
| | 48 h | 31000 | <10 | <10 | Absent | Absent | Pass |
| | 72 h | 32000 | <10 | <10 | Absent | Absent | Pass (72 h) |
| E | 0 h | 280000 | 70 | <10 | Absent | Absent | Fail |
| | 24 h | 290000 | 75 | <10 | Absent | Absent | Fail |
| | 48 h | 300000 | 80 | <10 | Absent | Absent | Fail (48 h) |
| | 72 h | – | – | – | – | – | Not-tested (spoilage) |

After three months of improvement. Table 11 demonstrates the results of the supplier SP2 QACI evaluation. Supplier D got a low-risk rating and the highest evaluation score (92%). Because they fully followed the rules and kept up their microbiological performance. This demonstrated the best results. Microbiological and documentation standards were met by suppliers A and C. They got 90% and 88% of their assessments. It means that they were at low risk. Supplier B was given a provisional certification with a moderate-risk score of 78%. Overall, the findings

indicate acceptable performance. However, several deficiencies in quality assurance practices were identified. Supplier E illustrated inconsistent compliance with established requirements. It failed to meet microbiological safety criteria. The high-risk classification and low evaluation score (50%) consider significant concerns regarding food safety and quality. The SP2 risk-based assessment framework integrated documentation review, compliance status, and microbiological risk. In order to provide a comprehensive evaluation of supplier performance (Table 10).

**Table 11: The SP2 QACI evaluation**

| Supplier | Selection Criteria | Approval Criteria (After 3-Month Improvement) | Risk Assessment (After) | Evaluation (%) (After) |
|---|---|---|---|---|
| A | Meets documentation and certification requirements | Approved – Passes microbiological baseline (72 h) | Low Risk | 90% |
| B | Meets basic compliance; medium QA maturity | Approved with conditions – Borderline microbiological baseline (72 h) | Moderate Risk | 78% |
| C | Minimum compliance; weak QA documentation | Approved – Passes microbiological baseline (72 h) | Low Risk | 88% |
| D | Strong compliance; meets all selection standards | Approved – Maintains microbiological baseline (72 h) | Low Risk | 92% |
| E | Meets minimal documentation; variable compliance | Not Approved – Fails microbiological baseline (48 h; spoilage before 72 h) | High Risk | 50% |

## The SP2 QACI comparative evaluation

Table 12 demonstrated how SP2 QACI results changed before and after an improvement. Supplier C gave the higher performance. It is going from high risk to low risk by 38%. Supplier A got better by 18%. It shows that microbiological stability and process improvements worked. Supplier D demonstrated higher performance in controlling the situation with a 2% rise. Supplier B demonstrated higher performance by 8%. It almost met the standards. Supplier E only got 2% better and still didn't meet microbiological standards. It is a sign of problems with food safety and quality.

**Table 12: The SP2 QACI comparative evaluation**

| Supplier | SP2 Before | SP2 After | Change | Interpretation |
|---|---|---|---|---|
| A | 72% | 90% | +18% | Achieved full microbial stability; major process improvement |
| B | 70% | 78% | +8% | Improved to borderline compliance; moderate progress |
| C | 50% | 88% | +38% | Largest improvement; shifted from high-risk to low risk |
| D | 90% | 92% | +2% | Maintained consistent high-level control |
| E | 48% | 50% | +2% | Minimal improvement; still microbiologically non-compliant |

The new supplier performance management framework SPI2 resulted in measurable improvement in supplier performance, particularly for supplier A and Supplier C, whose improvements increased by 18% and 38% respectively. This improvement enhanced with microbiological results and shelf-life stability.

**Microbiological performance: baseline vs current (After 3-month intervention)**

Before and after corrective actions. The SP2 framework improved microbiological results. The risk posed by the commissary poultry supplier. Under the SP1 assessment. The documentation submitted by Suppliers A and B was initially evaluated favorably. However, SP2 assessment identifies deficiency in microbiology and process control measures. Before the intervention, suppliers A and B were at moderate risk. While suppliers C and E were at high risk. Performance improved at the commissary following three months of quality assurance assistance. Low-risk suppliers A and C have verified that the shelf life is 72 hours. Supplier B improved in several aspects. Yet it remained precarious. SP2 found reliable suppliers like Supplier D with better performance. Supplier E remained classified as high-risk. It has with no observed improvement, demonstrating noncompliance with regulatory requirements. These findings demonstrated that SP2 outperforms SP1. Because it provides more accurate, and evidence-based assessment. The methodology encourages responsibility and supports targeted corrective actions. It also is a continuing improvement in microbiological food safety within centralized commissaries (Table 13).

**Table 13: Microbiological performance: baseline vs current (after 3-month intervention)**

| Supplier | Baseline Shelf-Life Outcome | Current Microbiological Result (72 h) | Improvement Status |
|---|---|---|---|
| A | Fail (24–48 h) | Pass (72 h) | Significant improvement – achieved full 72 h stability |
| B | Fail (24–48 h) | Borderline (72 h) | Moderate improvement – reached 72 h but with borderline TPC |
| C | Fail (0–24 h) | Pass (72 h) | Major improvement – from very poor baseline to full compliance |
| D | Pass (72 h) | Pass (72 h) | Maintained excellence – stable microbiological control |
| E | Fail (0–24 h) | Fail (48 h) → Spoilage before 72 h | No improvement – remains non-compliant |

The results showed that the integrated framework significantly has a hand on with both commissary team and suppliers to identify the operational risk and support the implementation of effective corrective action plans which improved the supplier's performance.

## Discussion

Food safety is crucial. As a result of global food supply chains. While previous studies demonstrate the criticality in food safety and supplier compliance programs, this study maintains the previously studied aspects in the qualitative quality assurance aspects in the new developed framework and in addition combines the microbiological profile of supplier to build new robust supplier performance management framework (SP2). This framework demonstrates the discrepancies between the traditional document-based review of supplier performance and the real microbiological performance within the centralized poultry commissary units in Egypt poultry supply chain.

Poultry products present a particularly high microbial risk because they spoil rapidly and are highly susceptible to contamination. Due to rapid microbial growth. For this reason, continuous monitoring throughout the supply chain is essential. In Egypt, quick service restaurants (QSRs) commonly depend on centralized commissary systems to ensure product consistency, operational efficiency, and quality control. However, this model also put most of the risk at the supplier level, meaning that a failure from a single supplier can affect the entire distribution network, potentially leading to food safety incidents, product recalls and reputational damage (Yevheniia, 2021).

Consequently, monitoring supplier performance must extend beyond routine inspections to include systematic evaluation of operational controls, microbiological standards and compliance with food safety management systems such as ISO 22000, BRC, FSSC 22000 and HACCP. Supplier performance evaluation should therefore address both product food safety and process reliability. Including hygiene practices, temperature control, traceability systems, staff training and deviation control procedures (CAPA). In Egypt, existing supplier evaluation approaches remain limited and often fail to fully consider local regulatory requirements, environmental conditions, operational constraints and the specific needs of centralized commissary systems. Addressing this limitation requires a comprehensive, risk based and context specific evaluation framework to support informed decision making and strength food safety governance (Radu et al., 2023). Accordingly, the main objective of this study was to develop a practical framework to help Egyptian QSRs evaluate and manage poultry supplier performance in alignment with centralized commissary standards. The framework integrates microbiological safety practices to ensure effective compliance.

A mixed-methods case study combined quantitative microbiological testing at critical commissary control points with qualitative evaluations of supplier quality assurance standards with qualitative assessment of supplier's quality assurance systems. Including certification status, traceability, corrective and preventive action (CAPA) effectiveness, and food safety culture. The initial results indicated no meaningful correlation between documentation-based evaluation method (SP1) and actual microbiological performance. Notably, Suppliers achieving high audit scores failed shelf-life validation. But those with intermediate administrative rating demonstrated superior real world microbiological safety.

These results illustrated that documentation-based quality assurance indicators are unable to forecast microbiological outcomes. To overcome this problem, 100 food industry experts collaborated to make an SP2-based Quality Assurance Compliance Index (QACI) framework. Risk-based assessment and empirical laboratory evidence are emphasized. Microbiological performance is immediately incorporated into supplier risk classification. This is done via weighted factors in supplier selection, risk assessment, approval, and periodic evaluation. The SP2 method effectively differentiated supplier performance. It also identified targeted corrective actions and enhanced microbiological outcomes over a three-month period. The approach also identified non-compliant suppliers. SP2 is more reliable, practical, and evidence based than SP1. Because it directly links quality assurance systems to food safety performance. It supports effective suppliers' management within centralized commissary systems.

Studies suggested that documentation-based compliance may reflect effective sanitation process. Saccol et al. (2013) reported that restaurants in São Paulo achieved an average compliance 78% with good practice. However, the present study demonstrates that reliance on documentation alone is insufficient to determine microbiological safety within high-risk poultry supply chain. Suppliers with high administrative evaluation scores, such as Supplier A (SP1 = 84.5%). It failed microbiological shelf-life validation within 24-48 hours. However, only Supplier D consistently met both microbiological criteria and compliance requirements. Demonstrating that documented Good Practices alone is inadequate to ensure food safety in high-risk food systems. Bukhari et al. (2021) reported significant microbiological contamination on food-contact surfaces in restaurants. Despite adherence to established hygiene protocols. These findings demonstrated that there is limitation upon evaluations based on checklists and paperwork have their limits. Microbiological monitoring and process control requires it to be checked regularly.

Solberg et al. (1990) illustrated that microbiological testing, documentation, and visual inspections are critical for food safety assessment, and it was agreed to our study. The audit, complaints and documentation based traditional supplier performance management SP1 approach did not reliably predict microbiological performance in this study. Suppliers with high compliance still showed rapid microbial growth and reduced shelf-life duration. In contrast, SP2 model incorporated routine microbiological monitoring. It is identified performance thresholds. It provides a more robust, risk-based method for supplier performance management over the supply chain phases of selection, risk assessment, approval and periodical evaluation.

These findings contravene those reported by Roquero and Esguerra (2025), who indicated that adherence to operational procedures alone does not guarantee microbiological safety in poultry supply chains. Similarly, Lahou et al. (2012) emphasized that formal regulatory compliance may suppress significant microbial hazards within manufacturing environments. In contrast, the present results suggest that, within centralized commissary systems, integrating laboratory derived data into supplier evaluation through the supplier performance management framework SP2 strengthens risk categorization, enhances process control and improves overall food safety monitoring. These outcomes are consistent with the observations of Osimani et al. (2013), who highlighted the importance of combining procedural compliance with actual microbiological assessment to achieve more reliable food safety management.

They indicated that Hazard Analysis Critical Control Point (HACCP), compliance and favorable audit outcomes do not ensure microbiological quality. Mistakes in

handling or operations result in microbiological contamination that affect consumer health. This study also demonstrated that providers with high SP1 audit, complaints and documentation-based scores failed to reflect microbiological shelf-life validation outcomes. It demonstrated the weakness of desktop driven assessments. These findings align with Wang (2022). His study identified deficiencies in coordinated food safety management systems. Also, His study observed that operational evidence seldom substantiates compliance assertions. These studies demonstrate that ensuring food safety requires continuous, evidence-based microbiological monitoring integrated into supplier evaluation systems. As it was implemented in SP2.

Zwietering et al., (2014) demonstrated that microbiological sampling has its limits. However, it is still a useful way to check process control. This study illustrated that suppliers with high level of documentation-based compliance failed shelf-life validation. Despite favorable audit evaluations. Although microbiological evaluation had certain limitations. Such as microbiological parameters proved critical for risk stratification. The SP2 paradigm involves structured quality assurance indicators with laboratory-based microbiological evidence.

Lupattelli et al. (2022) demonstrated that long-term microbiological monitoring, Good Manufacturing Practices (GMP), and Hazard Analysis Critical Control Points (HACCP) are essential for preserving hygiene in large food service systems. Thereby supporting this approach. This study reached a similar conclusion for poultry suppliers. It is characterized by high risk and uncertainty. Buchanan (1976) demonstrated that routine microbiological monitoring can reveal sanitation and procedural deficiencies. It may be rejected by inspectors. Thereby contributing to improved overall food safety.

The present results support the conclusion of Saxena et al. (2024). These studies emphasize that food safety governance should be comprehensive and risk oriented. Effective system therefore requires the implementation of structured approaches such as HACCP, ISO 22000, standards, routine microbiological monitoring, strong supplier relationships and continuous staff training. The findings further indicate that supplier risk assessment must include microbiological verification to ensure the safety of modern poultry supply chains. Accordingly, laboratory evidence (SP2) should be systemically incorporated into structures food safety management frameworks.

The findings of Saxena et al. (2024) underscore that food safety governance should adopt holistic and risk-oriented approach. Such governance frameworks typically include HACCP implementation and ISO 22000 systems, routine microbiological monitoring, strong supplier relationships, and continuous training programs.

Consistent with this perspective, the results from the present study indicated that effective supplier risk assessment requires microbiological verification to ensure the food safety of modern poultry supply chains. Accordingly, laboratory-based evidence in Supplier Performance Management Framework (SP2) should be systematically integrated into structured food safety management systems.

The present study is consistent with the findings of Saxena et al, who emphasized that effective food safety management systems and control parameters require not only regulatory compliance, but also strong operational controls, technical support, and robust suppliers' relationships. These results indicate that formal compliance alone does not guarantee food safety and highlights the critical importance of continuous microbiological monitoring. These results agreed with Brown et al. (2001), who emphasized HACCP systems and microbiological testing. They demonstrated that indicator organisms and microbiological patterns give more significant insights than pass or fail audits. This study illustrated that high Supplier Performance Management Framework (SP1) score suppliers failed to achieve microbiological performance standards. It showed that regulatory compliance without verification is insufficient. The SP2 framework follows these rules. Also, it facilitates the classification of supplier risk. By incorporation of microbiological counts, shelf-life validation, and risk-based sampling.

The study illustrated the necessity of behavior-focused interventions. It is supported by objective microbiological evidence. To improve food safety. This study found that when corrective actions were observed. The suppliers were reviewed using SP2. There were significant microbiological quality improvements. Castro et al. (2024) demonstrated that targeted training and practical controls results in significant decline in microbial contamination. These results demonstrated that audits and checklists are insufficient for resolving operational issues without continuous microbiological monitoring.

The findings agreed with Wang (2022). Wang (2022) is indicating that policy-driven and documentation-centric food safety systems typically underestimate the operational performance. High SP1 administrative compliance was not improved by microbiological outcomes. Despite apparent procedural compliance. Although it was evident that the processes were being followed. Gupta et al. (2011) reported that the continued presence microbiological contamination. The procedure indicates that contamination can occur at multiples stages and cannot be prevented by documentation alone.

The research suggests ongoing microbiological monitoring. It focused on corrective measures, and cohesive risk-based frameworks such as SP2. These approaches shift

food safety management from procedural compliance to measurable. It helps a sustained control of microbial risk within a complex QSR commissary supply chain.

This study agreed with Edstrom and Curran's (2003) assertion that system reliability relies on objective, and evidence-based monitoring. It does rather than presupposed compliance. They investigated laboratory water systems. This is agreed with our study. Also, suppliers who followed SP1 failed microbiological shelf-life validation. The approach identified hidden risks not detected by audits or documentation. It emphasized targeted monitoring needs. To identify latent microbial hazards within facilities.

The findings indicate that audits, documentation and complaint logs alone are insufficient to ensure microbiological safety in centralized poultry commissaries. To address this limitation, the present study developed and validated the SP2 Supplier Performance Management Framework. It integrates quantitative microbiological data with qualitative quality assurance indicators through the Quality Assurance Compliance Index (QACI). In comparison, the combined SP1and SP2 approach showed stronger alignment with actual microbiological performance outcomes. It enables more accurate risk identification and assessment. This integrated framework also facilitated targeted effective corrective actions and contributed to measurable supplier performance improvement.

After applying the newly developed Supplier Performance Management Framework (SP2), supplier performance showed clear improvement. Three suppliers were able to confirm a shelf life of 72 hours and most of them achieved higher performance scores. Although one supplier still did not meet the required standards.

The use of Supplier Performance Management Framework (SP2) supported evidence-based decision making. Also, it helped to identify risks more effectively and this facilitates the control and improvement processes. Overall, the results suggested that SP2 can strengthen food safety governance, improve supplier reliability and accountability. Also, enhance product consistency. However, given the study’s limited sample size duration and assessment scope, additional validation in larger and more complex supply chains would be beneficial.

## Study limitations and future research

The study has many limitations to be considered in interpreting and implementing its results:

1- The research conducted for a mixed case study in a single central poultry commissary suppling quick service restaurants in Egypt, this limits the generalization of the results to other geographical contexts.

2- The study conducted based on the commissary's key five poultry suppliers. This reflects small sample size.

3- The monitoring period after second supplier performance framework implementation is limited to three months which may not capture the long-term improvement action plans and further supplier performance evaluations.

Future opportunities arise for designing comprehensive Supplier Performance Management Frameworks, integrating quality assurance multi-dimensional perspectives to be applied across local and regional supply chain for further development, , effectiveness and adaptability. This will help with quality and food safety risk mitigation. Such a comprehensive framework will resolve the existing discrepancies and challenges posed by diverse SPM practices.

Today's technologies and Artificial intelligence (AI) innovation model and machine learning are now used to instantly analyze the supplier performance management process. for instance, the predictive model and machine learning can be provided with supplier performance trends and data which can predict the probability of physical, chemical and biological outbreaks as a proactive measures, this will integrate Multi-Criteria Decision-Making (MCDM) tools with AI and machine learning to predict supplier performance and food safety risks, which can dynamically weight the supplier performance KPI's and facilitate dynamic multi-dimensional risk score models that consider microbiological
data, previous performance, certifications, and corrective action history for more accurate supplier classification.

## Conclusion

The study successfully developed, analyzed and evaluated supplier performance management framework for poultry central commissaries serving quick service restaurants in Egypt.

The results demonstrated that the traditional supplier performance management framework based on supplier audit, documents review and complaints logs is insufficient to accurately reflect microbiological food safety performance of poultry supply to commissaries in Egypt. At baseline, only one supplier can maintain the poultry raw material stability for 72 hours despit the relatively high administrative evaluation scores. And after the new SP2 framework implementation, three suppliers achieved verified microbiological shelf-life consistency for 72 hours, while supplier performance evaluation scores significantly improved with the performance increase up to 38%.

The Study emphasized that the traditional supplier performance management (SP1), the audit and documentation-based evaluation method was insufficient to achieve the microbiological conformance and stability within the poultry industry or shelf life stability and performance within the centralized commissary systems. Achieving successful audit scores and positive complaints record did not consistently indicate effective hygiene and food safety criteria controls. Revealing a clear gap between formal regulatory compliance and actual microbiological results and outcomes. To manage this limitation, the study developed the Supplier Performance Management Framework (SP2). The newly developed framework integrates the Quality Assurance Compliance Index (QACI) with microbiological conformance profile of the suppliers. Over 3-month implementation period. SP2 improved the supplier performance by strengthening the supplier risk classification based on real assessment results, which enables the effective targeted corrective actions and increase the overall supplier performance reliability.

The Study results showed that supplier approval in high-risk poultry supply chain should not rely on individual administrative measures od documentations and supplier auditing, instead, the microbiological results and performance shall become an essential component of supplier performance management to ensure effective food safety governance in Egypt poultry central commissary system.

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# Stardom University

Stardom Scientific Journal of Natural and Engineering Sciences

- Stardom Scientific Journal of Natural and Engineering Sciences -
Peer Reviewed Scientific Journal published twice
a year by Stardom University

1st issue- 4th Volume 2026

ISSN 3756-2980