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STATE DIGITAL TRACEABILITY MODEL FOR FOOD PRODUCTS OF MICRO AND SMALL BUSINESSES IN E-COMMERCE CONTEXT

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Introduction. The rapid development of e-commerce, combined with the active engagement of micro and small enterprises in using online sales channels, gives rise to new challenges related to ensuring transparency, accountability, and safety within digital supply chains. The absence of a unified state digital traceability system that integrates the activities of micro and small enterprises into a single monitoring and control environment exacerbates the risks of non-compliance with product safety requirements and undermines consumer trust in online markets. An additional layer of complexity lies in the need to simultaneously overcome regulatory, technological, and organizational barriers that hinder the integration of micro and small enterprises into the digital economy while ensuring adherence to quality standards and transparency of product circulation at all stages of the supply chain in the online environment. Moreover, there is an urgent need to develop standardized protocols for API integration between state digital systems and online platforms, which would enable real-time product tracking, automate verification procedures, and support informed decision-making in the field of state regulation of digital commerce. Therefore, to address this issue, it is necessary to develop a conceptual model of state digital product traceability adapted to the operational and technological capabilities of micro and small enterprises in the context of e-commerce. This will ensure systematic regulatory oversight, transparent functioning of digital markets, and product safety for end consumers.

Analysis of recent achievements and publications. An analysis of the works of foreign experts reveals growing attention to digital traceability in the food sector, particularly concerning the application of RFID, QR codes, blockchain, and digital platforms. Šenk I., Ostojić G., Tarjan L., Stankovski S., Lazarević M. [1] focused on automated product identification; Zhou X., Lu H., Mangla S. K. [2] explored the impact of digital traceability on enterprise sustainability; Rashmi R. P., Neha S., Kamalakanta M. [3] examined general digitalization trends among SMEs, while Reddy P., Kurnia S., Tortorella G. L. [4] and Verna E., Genta G., Galetto M. [5] proposed framework or technological approaches without integrating government oversight. Mishra N., Mistry S., Choudhary S. [6] considered QR and blockchain solutions, yet without linking them to consumer actions or government platforms.

Thus, none of the reviewed works addresses the topic or challenges of creating a unified state digital traceability model integrated with national platforms and tailored to micro and small food enterprises in the context of e-commerce. The uniqueness of the proposed concept lies in combining QR identification, consumer interaction, risk-based monitoring, and automatic incident response within a single digital ecosystem.

Objectives of the article. Development of a conceptual model for state digital traceability of food products, aimed at integrating micro and small manufacturing enterprises into the e-commerce system by ensuring transparency and safety in the circulation of food products through online sales channel.

The main material of the study. In the context of the development of the digital economy and the rapid expansion of e-commerce, there is an objective need to ensure transparency and accountability in the circulation of food products sold through online channels by micro and small manufacturing enterprises. The lack of appropriate traceability mechanisms in this sphere creates risks for consumer safety, limits the capabilities of state quality control, and complicates the integration of small business actors into digital food markets in line with current regulatory and market requirements. Ensuring digital traceability in this segment is a necessary condition for enhancing the competitiveness of micro and small producers, developing e-commerce in the food sector, and implementing systematic real-time state-level control over product circulation.

Therefore, in this context, there is a need to develop a conceptual model of state digital traceability that combines regulatory, technological, and institutional mechanisms, while ensuring data interoperability between state registries, producers, and online platforms.

The next step is to outline the step-by-step implementation of the concept for digital registration and regulation of the activities of micro and small manufacturing enterprises and their warehouses involved in the online sale of food products, as well as the regulation of online platforms, e-shops, and marketplaces through which food products are distributed (including specific requirements for micro and small producers and API integration of the "Trek.Food" system with online platforms);

Let us consider a detailed scheme of digital registration and verification of a micro or small food enterprise in "Diia.Business" and "Trek.Food", see Fig. 1.

The data presented in Fig. 1 illustrates the verification algorithm for micro and small enterprises within the state digital system "Trek.Food", which forms an integral part of the institutional cycle of registration and confirmation of food production safety. This process models an integrated logic of interaction between the state platforms "Diia.Business", "Diia.Inspector", the State Service of Ukraine on Food Safety and Consumer Protection, and the central hub for verification and traceability "Trek.Food" which functions as an analytical and regulatory platform with digital linkage to the capacities and risk profiles of enterprises.

The initial step involves the registration of a micro or small enterprise on "Diia.Business" through the completion of legal forms. This stage is not merely formal, as the entered data is automatically routed via "Diia. Inspector" to the State Service of Ukraine on Food Safety and Consumer Protection, where the registration code is checked against the enterprise's operational capacities. This verification performs a dual function: it confirms the legal validity of the enterprise and classifies it based on its risk level. Only after a positive result does the enterprise obtain "registered" status and is automatically transferred to the "Trek.Food" platform, where the second stage visual and documentary verification of the premises for safety compliance is carried out. This transition is critically important, as registration in "Diia.Business" confirms only the legal status, whereas "Trek.Food" enables the assessment of the physical condition and functional safety of the production environment.

On the platform, the enterprise uploads photographic evidence of key facilities, including production areas, storage for raw materials and finished products, packaging stations, and information about suppliers. These five blocks correspond to the key critical control points under the HACCP system, enabling the inspection of working conditions and evaluation of the enterprise's compliance with international food safety standards.

Once the data is uploaded to the system, an internal verification request is generated for the State Service of Ukraine on Food Safety and Consumer Protection, which, using "Diia.Inspector", analyzes the accuracy and completeness of the provided information. In case of discrepancies, the enterprise receives a digital request for additional inspections, corrections, or procedural adjustments. This mechanism of corrective intervention allows the business to resolve issues before any potential sanctions are imposed implementing a practical, preventive model of state response.

When all submitted information is verified and meets the principles of HACCP, the enterprise receives the "verified" status in "Trek.Food", which is then automatically integrated into the enterprise's profile in "Diia.Business". This ensures both formal legal registration and digital recognition of safety compliance.

This approach has several key advantages. First, it creates a transparent and predictable entry logic into the market for micro and small enterprises, enabling informal actors to become legal participants through a simple, fully digital two-phase procedure. Second, the availability of photos and data on production facilities enables the state to partially replace physical inspections, significantly reducing the regulatory burden. Third, the standardization of blocks (storage areas, packaging, batch tracking) allows for the development of modular risk analytics, forming the foundation for further automated assessments and scenario-based regulatory decisions.

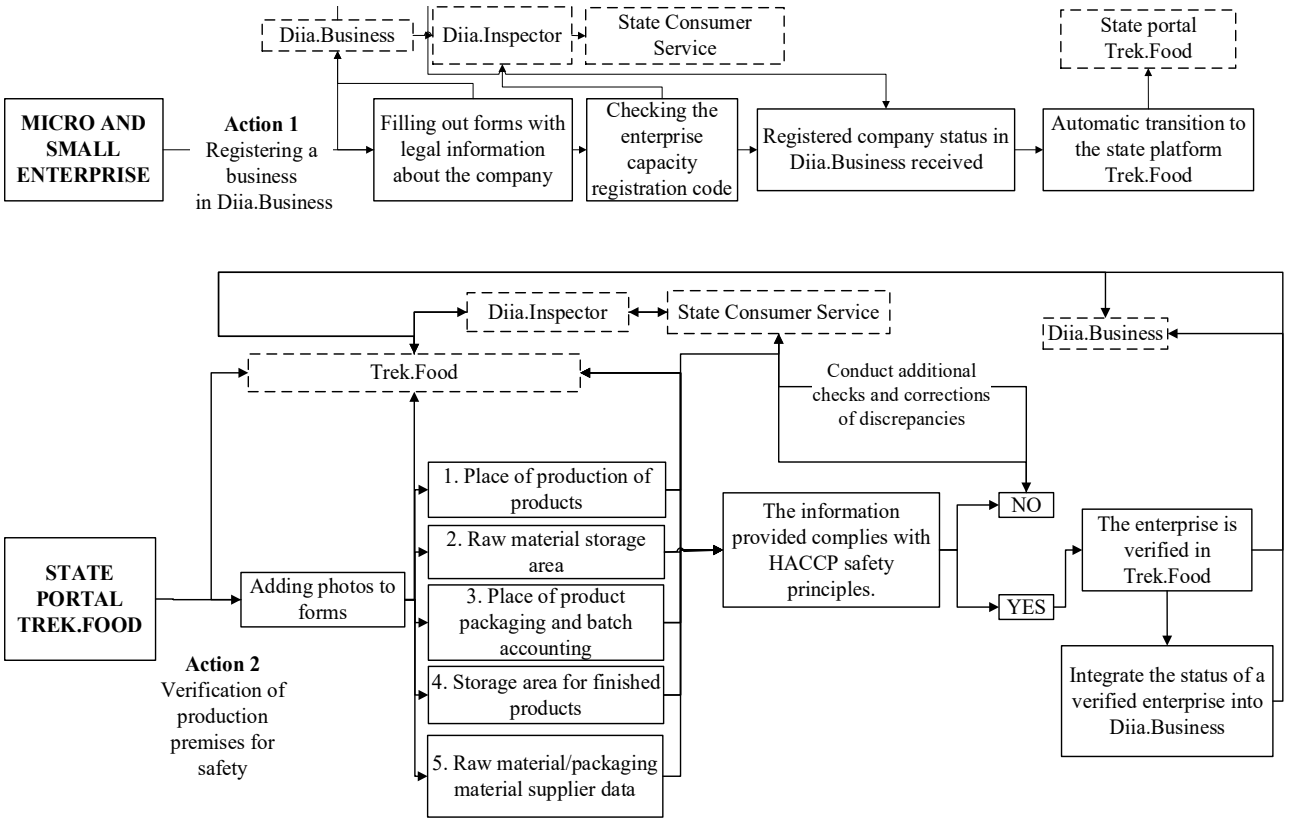

Figure 1. Digital registration and verification of a micro or small food enterprise in "Diia.Business" and "Trek.Food"

Source: developed by the author

Let us examine a detailed scheme of digital registration and verification of warehouse facilities of a micro or small food enterprise in "Diia.Business" and "Trek.Food" see Fig. 2.

According to the example in Fig. 1, on Fig. 2 illustrates the initiation of the registration process for warehouse facilities of a micro or small enterprise in "Diia.Business", where the business fills out the provided forms with its legal data. This data is automatically transmitted via "Diia.Inspector" to the State Service of Ukraine on Food Safety and Consumer Protection, which verifies the previously issued production facility registration code to confirm the compliance of the declared warehouse with the registered parameters.

If the result is positive, the warehouse receives the status of a "registered facility", which serves as a prerequisite for automatic transition to the "Trek.Food" digital platform, where the key phase of verifying the premises begins focused on compliance with HACCP principles and general sanitary, storage, and logistics requirements. At the next stage, the enterprise uploads photo documentation and supporting data to the corresponding forms on the "Trek.Food" system. Digital algorithms then verify five main blocks: 1) raw material storage area; 2) finished product storage area; 3) presence of temperature control systems; 4) humidity and sealing compliance, with documented batch tracking to ensure traceability; 5) data on logistics companies involved in transportation [3, 4, 5]. Such structuring enables standardized inspection based on a modular template that aligns with HACCP requirements and integrates into an automated risk audit system [5].

After the information is submitted, a verification process is initiated by the State Service of Ukraine on Food Safety and Consumer Protection through "Diia.Inspector", which analyzes the accuracy and reliability of the provided data. If discrepancies are found, a correction request is sent to the enterprise. If the information fully complies with safety principles, the system assigns the status warehouse facility verified in "Trek.Food", which is automatically integrated into the enterprise's profile on the "Diia.Business" platform.

This demonstrates a consistent digital logic in which a physical warehouse is registered as a legal unit and undergoes a multifactor verification of its operating conditions, enabling the state to monitor not only the production process but the entire logistics and storage chain within the state ecosystem of electronic and express commerce. The inclusion of parameters such as humidity, temperature, sealing, and batch tracking

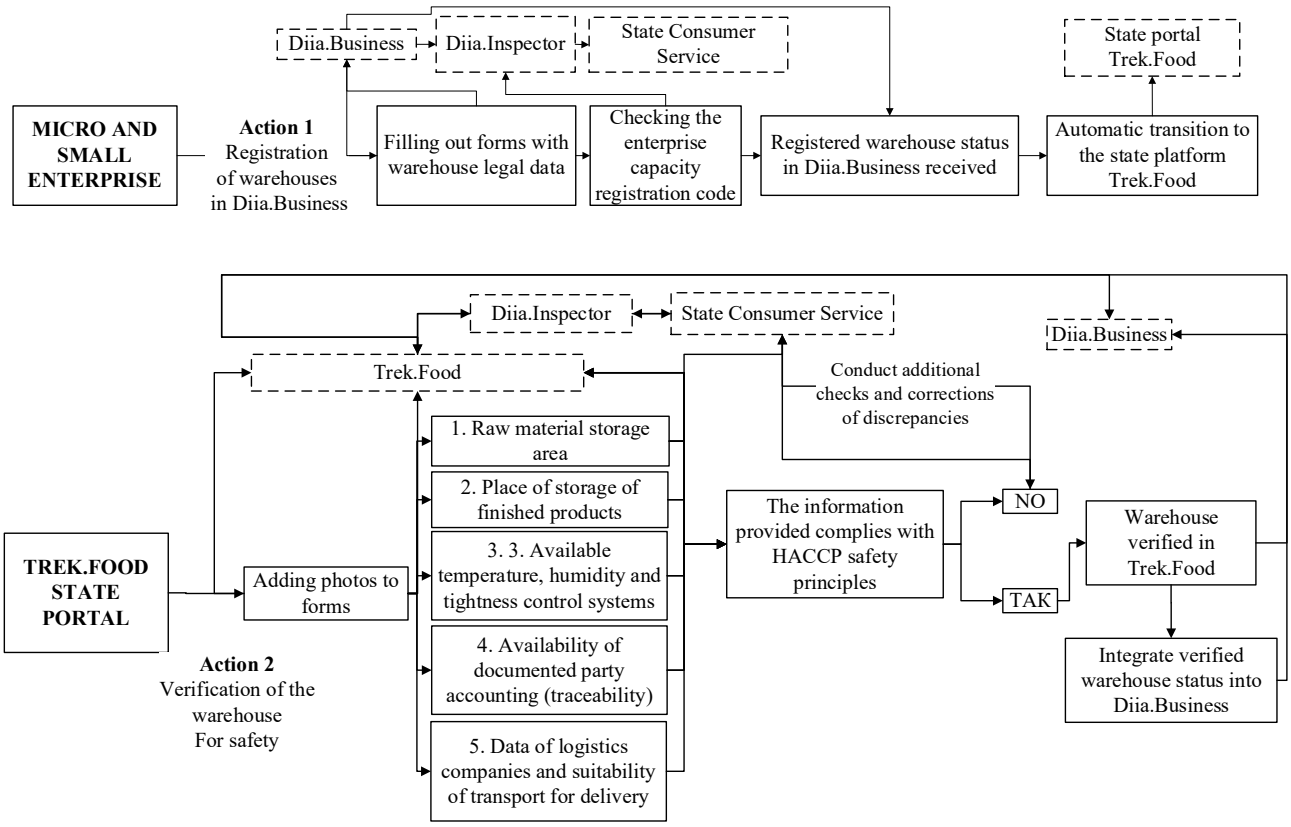

Figure 2. Digital registration and verification of warehouse facilities of a micro or small food enterprise in "Diia.Business" and "Trek.Food"

Source: developed by the author

is particularly significant, as it transforms the warehouse from passive infrastructure into a critical risk management point [3, 4, 5]. In this context, the state acts as a digital moderator of traceability conditions with capabilities for adaptive intervention, analytics, and support for market participants. As a result, the proposed model demonstrates a high level of institutionalization of the digital state oversight system, in which registration, verification, documentation, and status integration occur within a unified digital environment, minimizing human error and maximizing safety standards.

Let us consider the structure of filling in the enterprise's personal account in "Trek.Food" for confirming production safety and obtaining a digital temporary product safety certificate, see Fig. 3.

Fig. 3 illustrates a comprehensive stage of building the digital model of state control within "Trek.Food", which concerns the detailed registration of raw material sources, suppliers, logistics operators, production facilities, and digital batch accounting in the context of electronic food commerce. The first actions of a micro or small food enterprise are the authorization in "Trek.Food", after which begins the gradual filling out of forms detailing the categories "Raw materials and suppliers", "Transport and logistics operators" and "Production premises".

Within the first block "Raw materials and suppliers", the enterprise is obliged to indicate: 1) type of product; 2) type of raw material; 3) names of suppliers; 4) availability of phytosanitary or veterinary certificates; 5) certificate of origin or conformity of the product, which ensures full transparency of sources and allows the formation of an open system of trust between the producer, regulator, and consumer.

In the parallel second block "Transport and logistics operators", the enterprise provides detailed information regarding: 1) transportation; 2) type of transport; 3) sanitary requirements for transport; 4) availability of GPS traceability systems; 5) availability of temperature, humidity, and airtightness control systems; 6) a contract with a responsible carrier, which allows the state to control risks in the logistics segment, which is traditionally the least regulated in electronic commerce and requires the implementation of cold supply chain standards.

The third block "Production premises" includes the addition of information regarding available technological maps, personnel requirements, medical books, sanitary standards, daily raw material accounting,

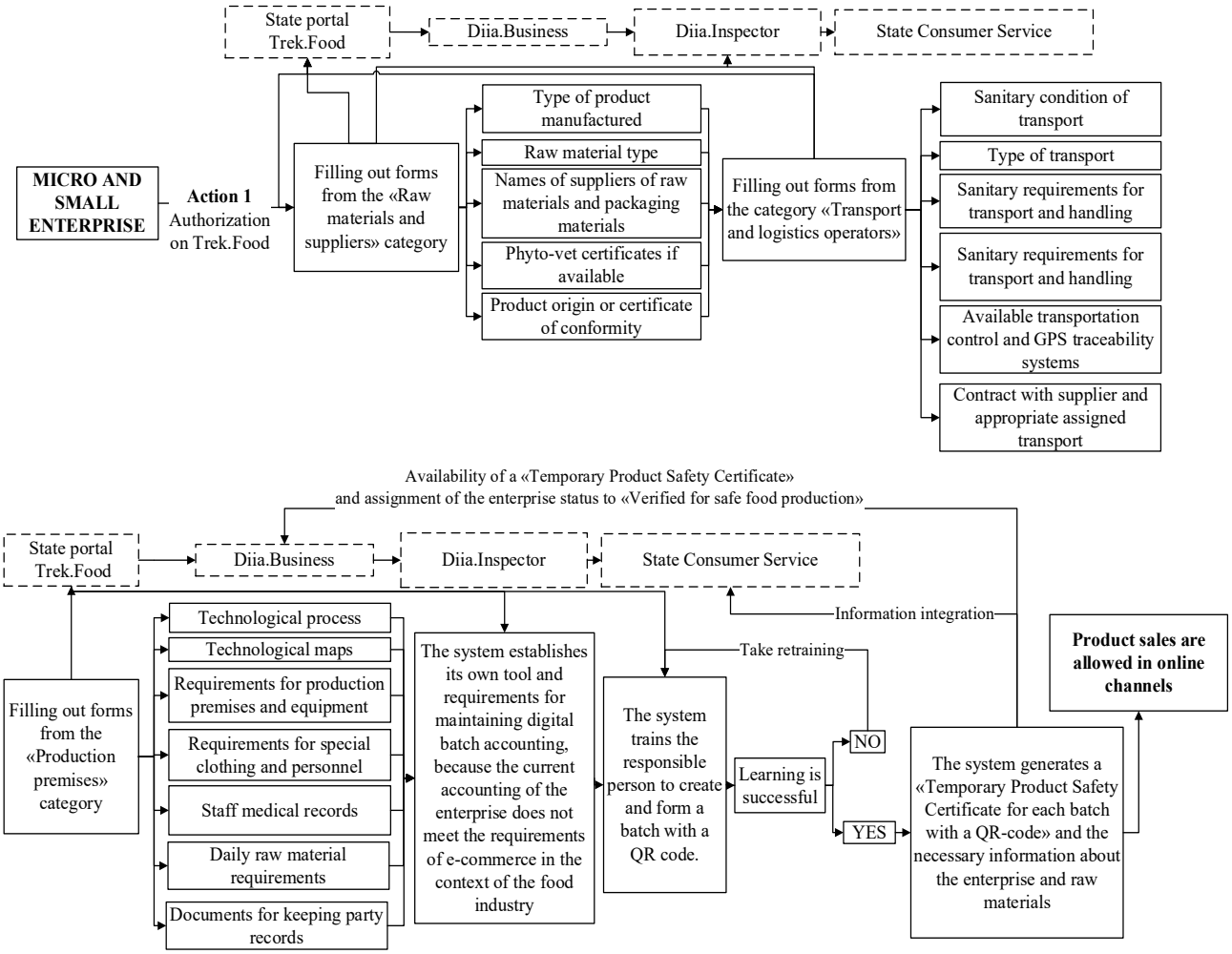

Figure 3. Filling in the enterprise's personal account in "Trek.Food" to confirm production safety and obtain a digital temporary product safety certificate

Source: developed by the author

documentation on batch tracking and the overall technological process. This enables the system to assess the internal production quality at the level of the institutional HACCP model, but taking into account the needs of electronic commerce, namely: 1) turnover speed; 2) seriality; 3) labeling; 4) batch personalization [1, 2, 6]. If the enterprise does not meet these requirements, it is obliged to undergo instrumental modernization of batch tracking, which will be initiated through "Diia.Inspector", and only after that it will be possible to obtain the "Temporary Product Safety Certificate".

After verification of the mentioned blocks, the enterprise receives the "Temporary product safety certificate" and the status "Verified for safe food production". However, under conditions of dynamic commerce, this is not enough, so the scheme includes a digital training module, where a specifically responsible person from the enterprise is required to complete a course on forming "QR-coded batches", after which the system checks the results and, in case of a positive outcome, allows the formation of future batch records and product sales through online channels. This integrates the concept of digital personnel competence into the state model of access to the online market, which has not existed before in the Ukrainian regulatory field.

At the final stage, each product batch receives a personalized QR-certificate containing information about the enterprise, origin of raw materials, logistics, and the batch accounting system, after which the product can be sold online with a verified safety status [1, 6]. As a result, a digital passport for each food product is formed, which will become part of a new regulatory model where "the government makes decisions based on real data".

Let us consider the digital mechanism of product batch registration and the formation of a "QR-identification" code in "Trek.Food" for micro and small food enterprises, see Fig. 4.

Fig. 4 demonstrates the mechanism of food product batch registration, their identification via "QR-codes" and verification followed by certification, forming a new standard of state control in the field of electronic and fast commerce. This stage effectively institutionalizes a digital culture of real-time traceability, transforming the "QR-code" from a labeling element into a full-fledged tool of a legally binding digital product passport [1, 5, 6]. The process begins with the authorization of a micro or small enterprise on the "Trek.Food" system, after which the batch entry module is activated under the "Production premises" category. The producer fills in critically important data, including the production date, expiration date, quantity of manufactured products, batch composition, assigned batch number, and the "QR-code". This set of attributes creates a unique digital profile for each product batch, allowing it to be controlled regardless of the distribution channel.

At the moment of batch creation, the system verifies the accuracy of the entered data. If the information is complete and valid, the "QR-code" is automatically assigned, and the batch receives a "verified" status [6]. In case of missing or incorrect data, the system sends an alert to the State Service of Ukraine on Food Safety and Consumer Protection via "Diia.Inspector", and a ban on the sale of that batch is imposed. Thus, this mechanism effectively eliminates the possibility of "grey" products circulating without digital identification in the online space. The "QR-code" assigned to each batch serves as a unique marker that fulfills declarative, regulatory, and consumer functions.

When scanned, the "QR-code" provides data on the temporary safety certificate, the legal status of the enterprise and its facilities, product compliance, and raw material quality certificates. Additionally, it displays complete information about the logistics operator, packaging, production date, and composition, forming a digital traceability picture for both regulatory authorities and end consumers.

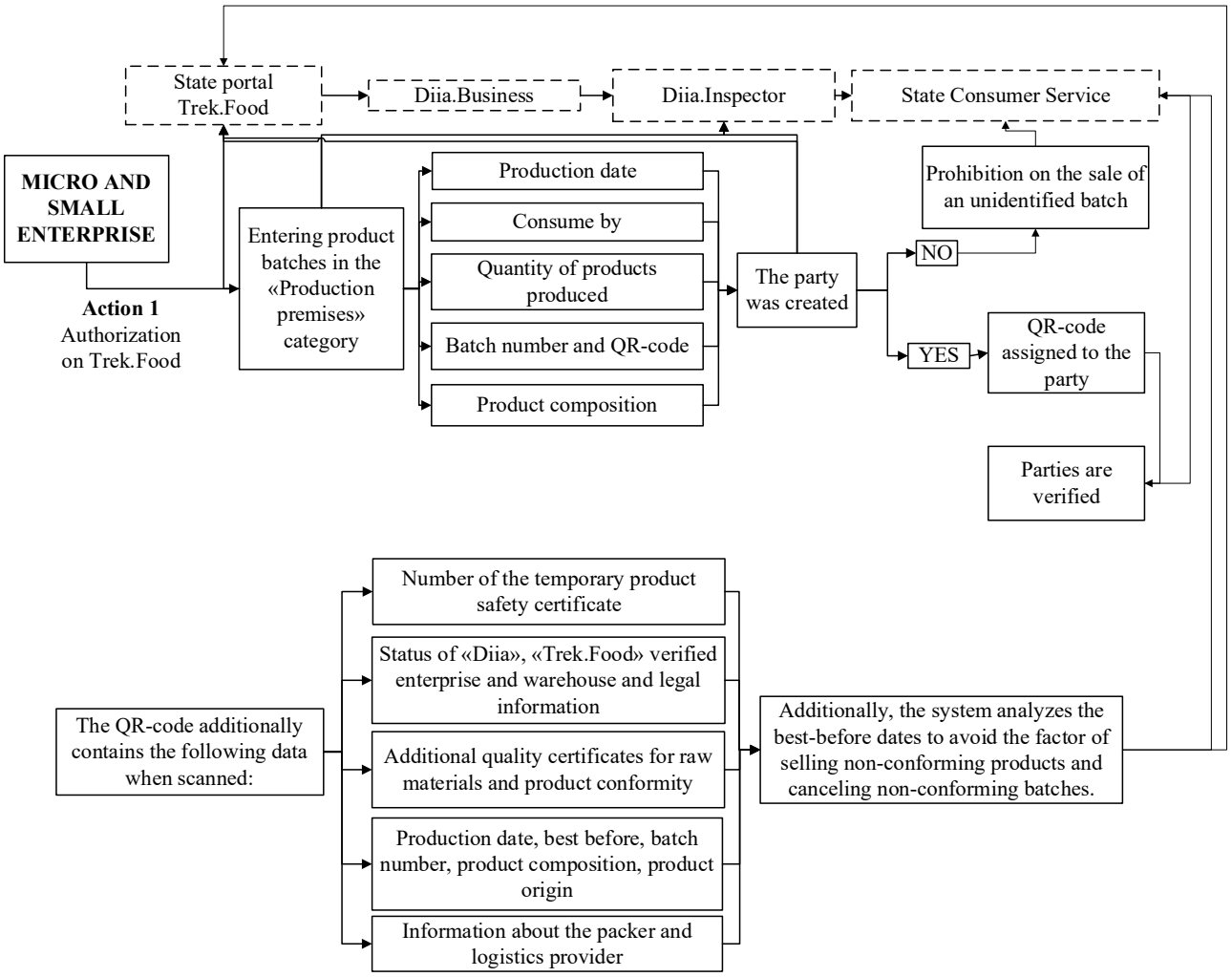

Figure 4. Digital mechanism of product batch registration and the formation of a "QR-identification" code in "Trek.Food" for micro and small food enterprises

Source: developed by the author

A significant innovation is that the "Trek.Food" system automatically analyzes the expiration date of each batch, and in case of exceeding the limit or entering conflicting data, the batch is automatically annulled with a sale prohibition. This approach will, for the first time, enable operations without a controlling inspector in a "24/7" mode.

As a result, this mechanism will enable the implementation of the "dynamic certificate" principle, where each batch is an independent legal unit with a digital profile that undergoes auditing not only at the time of production but also at the point of consumption. This radically differs from the traditional model of certifying the producer as an institution and, for the first time in Ukrainian practice, allows the establishment of batch-focused regulatory logic, where the right to sell is determined not by the business entity but by the status of a specific batch confirmed by data from production, logistics, and documentation blocks.

Let us consider the digital supply chain of food products and the cyclical state supervision through "Trek. Food", see Fig. 5.

Fig. 5 shows the process of receiving an order by a micro or small enterprise, which is placed by a consumer through the relevant online platform. The order is then automatically redirected to the "Trek.Food" platform to link the order to the corresponding product batch. This stage is critically important, as it allows the state to trace each unit of goods not only as a production batch but also as a fact of its commercial movement in the digital space. If the enterprise has not created a batch or has failed to verify it, the sale is automatically prohibited, demonstrating the principle of unconditional regulatory blocking of non-transparent transactions.

After order confirmation, the platform allows the sale, and the enterprise proceeds to prepare the product according to hermetic packaging requirements, selects a logistics company, and generates a "QR-code" tied to the specific batch. After that, the "Trek.Food" system records the creation of the order, assigns it to a batch, and initiates digital logistics, whereby the package is handed over to the designated carrier, and all data about the route, supplier, temperature, and certification are already embedded in the "QR-code" [6].

At the moment of delivery, the customer scans the "QR-code" on the packaging. If discrepancies are detected, the customer creates an incident via the "Trek.Food" online form, which is automatically recorded in the system. If the customer receives the order without incident, the supply chain is completed and recorded

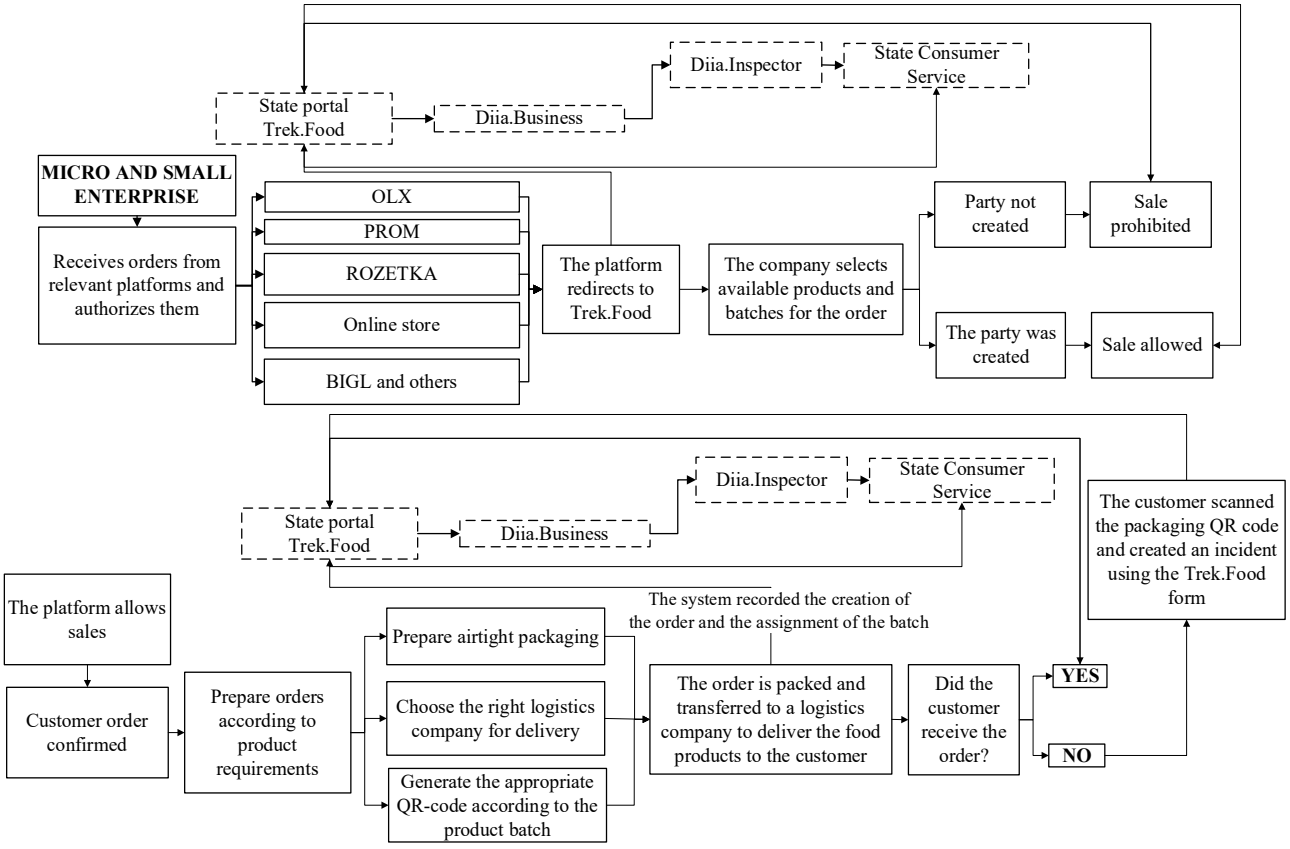

Figure 5. Digital supply chain of food products and the cyclical state supervision through "Trek.Food"

Source: developed by the author

as successful. Otherwise, a mechanism of digital audit, inspection, and state control is triggered, aiming to stop the illegitimate circulation of food products and prevent repeated violations through sanctions, reputation downgrade of the enterprise or temporary or permanent license suspension. A key innovation here is that no single product unit reaches the consumer without digital verification, and scanning the "QR-code" acts not only as an informational action but also a legal one that can initiate administrative consequences [1].

Thus, a cyclical model of trust is formed, where every actor (producer, online platform, consumer, logistics, and the state) becomes not only a link in the supply chain but also an active participant in quality control through digital integration, establishing the principle of "the order as the regulatory launch point", where the fact of an electronic transaction automatically activates state compliance verification.

The next logical step is to consider the implementation of the mechanism in Fig. 5 from the consumer's perspective, namely, the purchase of products online from a micro or small food enterprise with the built-in incident reporting mechanism in the "Trek.Food" system, see Fig. 6.

Based on the data shown in Fig. 6., the final mechanism of digital control over food products is demonstrated, in which the consumer becomes a key element of state supervision, completing the logistical and regulatory route of a batch from a micro or small food enterprise [1, 6]. The depicted online commerce platforms ("OLX", "PROM", "ROZETKA", "BIGL", etc.) represent not only sales channels but also act as technological gateways that transmit the product status, order, and related information to the state traceability system "Trek.Food", enabling the formation of a unified digital transparency chain from producer to end user.

Thus, according to Fig. 6., the consumer, upon authorization on the platform, selects a product, enters personal data, delivery method, and receives preliminary order information, which is transmitted from integrated systems to the state traceability system "Trek.Food". Upon receiving the product from the logistics service, the consumer scans the "QR-code" on the packaging and verifies product conformity (production date, composition, raw material origin, legal status of the producer) and opens a parallel real-time interaction function with "Trek.Food" to create a digital incident (if necessary). In case of positive conformity of the product to the declared characteristics, the order is considered completed, and the consumer may leave digital feedback within the "Trek.Food" system. If a discrepancy arises, the consumer must create an incident by scanning the "QR-code", which activates the digital regulatory verification process. The incident is automatically sent to the analytics module of the state portal "Trek.Food", which, with the participation of the State Service of Ukraine on Food Safety and Consumer Protection and the digital inspector "Diia.Inspector", classifies the discrepancy into the following categories: 1) hazardous to health; 2) safe for health but violates declared pre-sale parameters. This reflects the core principles of a risk-oriented response model, where the primary trigger is the consumer's digital footprint rather than just a scheduled audit.

In the case of a safe discrepancy, the enterprise is given the opportunity to correct the situation by implementing corrective actions. If the violation is not resolved, the corresponding product batch is removed from the system, access to the "Trek.Food" traceability platform is temporarily suspended, and the enterprise's status in "Diia.Business" is updated to "Enterprise at risk".

In the event of detecting a hazardous factor, the system applies the following sanctions: 1) blocking of online sales and financial operations; 2) temporary or complete prohibition of product sales, changing the enterprise status from "Safe food enterprise" to "Hazardous food enterprise", as well as imposing fines and initiating additional audits by the State Service. Therefore, even a single negative consumer interaction with a batch can trigger a full cycle of inspection of the entire production, transportation, and storage chain. A key regulatory tool is the reputation system built on the aggregated number of incidents. If their number exceeds allowable thresholds, the enterprise is automatically classified as at risk. In such cases, the temporary product safety certificate is annulled, access to the "Trek.Food" system is lost, and partnerships with online trading platforms are blocked.

Conclusions. Summing up the conducted research, a conceptual model of state digital traceability of food products produced by micro and small enterprises in the context of electronic commerce was developed. This model enables the integration of institutional, technological, and regulatory mechanisms into a unified digital control ecosystem. Scaling this model should ensure transparency and accountability in the circulation of food products, a high level of product safety and quality for consumers, and the creation of a favorable environment for the legal operation of micro and small producers in online sales channels.

The obtained results can be used to shape public policy on digital transformation in the field of food safety, the development of e-commerce, and the improvement of state supervision procedures in real time.

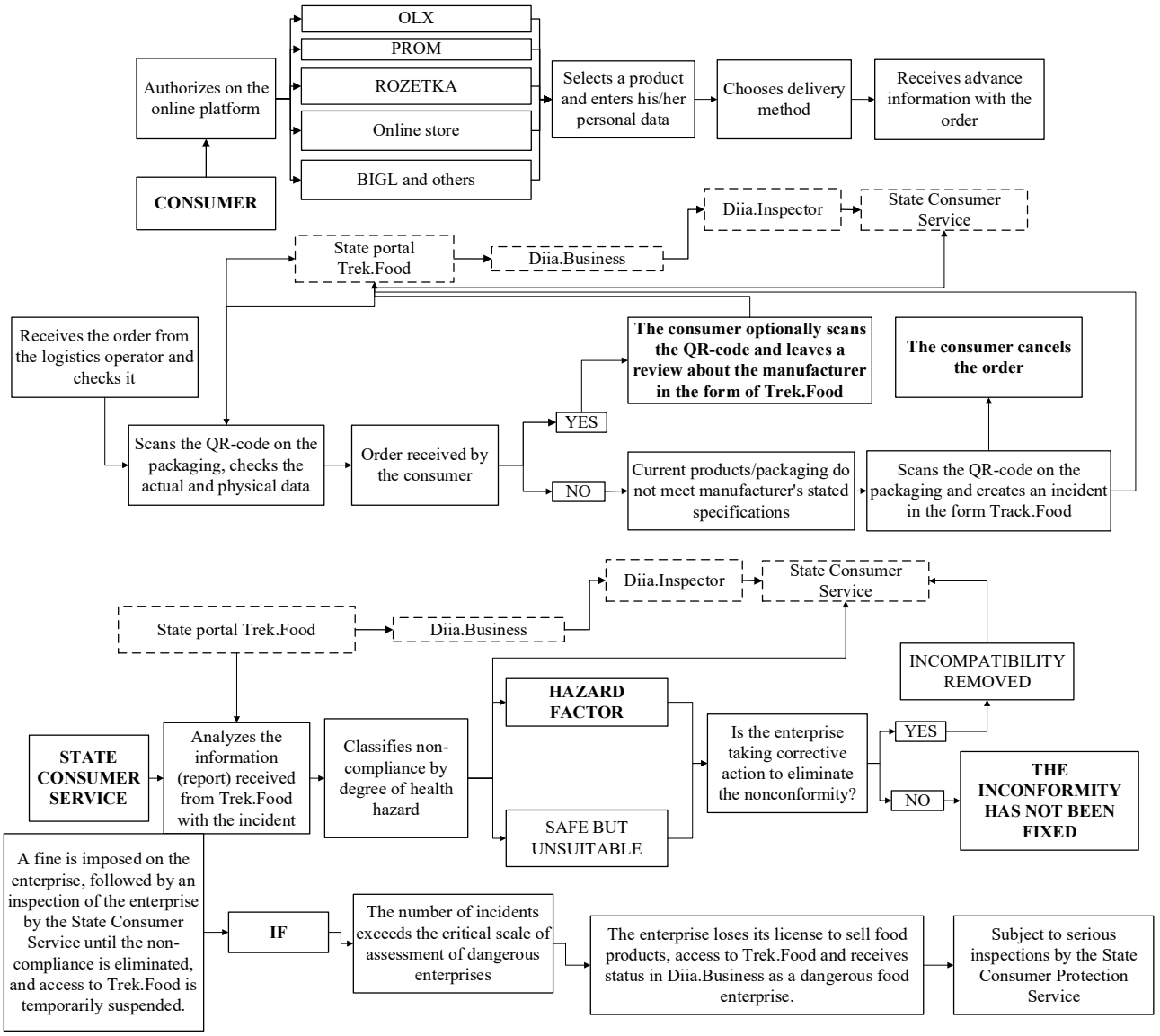

Figure 6. The purchase of products online from a micro or small food enterprise with the built-in incident reporting mechanism in the "Trek.Food" system

Source: developed by the author

Future research prospects include empirical testing of the model's effectiveness at the regional level and analyzing the impact of digital traceability implementation on the economic resilience of micro and small enterprises engaged in electronic commerce.

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Conceptual model of state digital traceability of food products of micro and small enterprises in the context of e-commerce.

The article presents the state conceptual model of digital traceability "Trek.Food", which integrates the platforms "Diia.Business", "Diia.Inspector" and QR-identification tools into a unified control ecosystem. A digital verification architecture for production and storage facilities has been developed, enabling real-time audits of compliance with HACCP standards, supported by risk-based regulatory analytics. Mechanisms for dynamic QR safety certificates have been introduced as digital passports for product batches, shifting the focus of state control from the business entity to each specific product batch. A methodology of cyclical digital oversight is proposed, enabling automatic inspections and corrective actions through a single digital environment triggered by electronic transactions or consumer QR-code scans, thus enhancing accountability across supply chains. The model reduces regulatory burden, minimizes the need for physical inspections, increases transparency, and builds consumer trust in online food sales. The integration of staff digital competencies and the implementation of a reputational monitoring system further promote voluntary compliance with safety standards. Ultimately, the model ensures flexible state oversight and facilitates simplified access for small food businesses to online markets.

Key words: digitalization, traceability, food industry, government regulation, e-commerce, small food businesses, QR-dynamic certificate, QR-batch.

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Модель державної цифрової простежуваності харчової продукції мікро- і малого бізнесу в контексті електронної комерції.

У статті було представлено державну концептуальну модель цифрової простежуваності «Трек.Food», яка поєднує поточні цифрові державні платформи «Дія.Бізнес», «Дія.Інспектор» і цифрові інструменти і механізми QR-ідентифікації, що формує єдину екосистему контролю. У дослідженні було сформовано покрокову архітектуру цифрової верифікації та реєстрації виробничих і складських потужностей, яка дозволяє проводити аудити відповідності стандартам HACCP в реальному часі із залученням аналітичних модулів ризик-орієнтованого регулювання. Проаналізовано механізми створення динамічних QR-сертифікатів безпечності продукції, як елементів цифрового паспорта кожної партії, що радикально відрізняється від традиційних моделей сертифікації через перенесення фокусу державного контролю із суб'єкта господарювання на кожну конкретну партію продукції. Створено методологію циклічного цифрового нагляду, у якій взаємодія між споживачами, виробниками, логістичними операторами та державними органами реалізується через єдине цифрове середовище, яке дозволяє автоматично ініціювати перевірки та коригуючі дії на основі факту електронної операції або сканування QR-коду споживачем, формуючи новий рівень відповідальності у ланцюгах постачання. У порівнянні з існуючими підходами, запропонована модель значно знижує регуляторне навантаження на бізнес, скорочує потребу у фізичних інспекціях, забезпечує прозорість та підзвітність кожної транзакції та підвищує рівень довіри споживачів до онлайн-каналів збуту харчової продукції. Слід виділити, що інтеграція цифрової компетентності персоналу харчових підприємств у процес формування QR-кодованих партій та впровадження репутаційної моделі ризик-орієнтованого моніторингу забезпечить стабільне функціонування системи, покращить добровільну відповідності бізнесу до стандартів безпечності і якості. Загалом запропонована концептуальна модель дозволить створити державний інструментарій обґрунтованого, автоматизованого і гнучкого нагляду, а для мікро- та малого харчового бізнесу реалізувати спрощений доступ до онлайн збуту харчової продукції.

Ключові слова: цифровізація, простежуваність, харчова галузь, державне регулювання, електронна комерція, малі харчові підприємства, QR-динамічний сертифікат, QR-партія.