LATFORM FOR EVALUATING THE PRODUCTIVE CHAIN AND DIRECT MARKETING OF ALPACA FIBER TO PROMOTE BUSINESS AUTONOMY

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Abstract

Llamayu has emerged as a pivotal tool in enhancing the valuation of the alpaca fiber production chain, directly benefiting small producers in the high Andean regions. This study assesses Llamayu's impact on the economic, operational, and market access aspects of alpaca fiber producers. Results show a 25% average increase in producer incomes, attributed to direct marketing facilitation and favorable price negotiations, eliminating intermediaries. Operational efficiency has improved with a 20% reduction in production chain management time, enabling producers to focus on enhancing fiber quality. Llamayu promotes sustainability and business autonomy through improved transparency and traceability, ensuring high-quality standards to meet global market demands. Future research should explore long-term impacts and the integration of emerging technologies like ViViD, enhancing product presentation dynamically. Llamayu significantly enhances the alpaca fiber value chain, fostering economic and sustainable development in high Andean communities.

Introduction

Alpacas are primarily raised for their fiber, which is highly valued in the textile industry for its softness, durability, and lightness [1]. Peru, the world leader in alpaca breeding, is home to 71.7% of the global population [2], with a significant concentration in the Puno region, which holds 39.61% of the country's alpaca population and accounts for 87% of national production [3]. Alpaca fibers are not only a crucial raw material for fashion but also significantly contribute to the economy of the high Andean regions, representing over 80% of local family incomes [4].

The global alpaca fiber market has shown steady growth, with projected demand increasing at an annual rate of 3.2% over the next decade [5]. This increase is driven by growing consumer preference for natural and high-quality products, greater awareness of the benefits of alpaca fiber, and a general rise in living standards [2]. Fibers from South American Camelids are in high demand in the international textile industry [6]. Peru, considered a leader in alpaca textile exports, reached 23 countries in 2019, including markets in Europe, Asia, and North America [7]. Compared to the study up to 2024, there have been significant advances in the genetic improvement of alpacas in southern Peru, with notable improvements in alpaca fiber fineness and production by 25% and a growing preference for white fleece, especially in the Huacaya breed [8].

Alpaca breeding is vital for the economy of the high Andean regions, where most of the production is concentrated. In 2019, Peru's alpaca population reached 4,449,506 heads, with over 80% in southern regions such as Puno, Cusco, Ayacucho, Arequipa, and Huancavelica [2]. Alpaca breeding and fiber production are crucial for the economic development of producers in 17 regions of Peru, including Puno, Ayacucho, Cusco, Arequipa, Apurímac, and Huancavelica. Peru leads global production with 85% of the world's alpaca population, distributed across 3.6 million specimens, dominated by the Huacaya breed (80.4%) and Suri (12.2%). The main concentrations are in Puno (39.6%), Cusco (14.7%), Arequipa (12.7%), Huancavelica (8.3%), Apurímac (5.9%), Ayacucho (2.8%), and Pasco (1.8%) [9]. Camelid breeding is one of the most important productive and economic activities in the high Andean zone of Peru, as it accounts for between 70% and 80% of the annual family income of its producers [10]. Small producers heavily depend on their alpaca herds for their livelihood, and improvements in direct fiber marketing could significantly increase their economic benefits [11].

The global value chain theory applied to the Peruvian alpaca fiber chain reveals a fragmented-concentrated structure of supply and demand [12]. State standardization impacts chain governance, with different governance modes coexisting within and between chain segments [13]. The productive chain ensures consistent quality, optimizing the marketing process [14]. Creating a digital direct marketing platform could provide small producers with greater business autonomy, facilitating direct sales and improving efficiency and transparency in commercial transactions [15].

Leadership initiatives among producers and the adoption of improvement technologies in marketing are crucial to addressing current sector challenges, such as market access and limited income [16];[17]. A recent study in Peru showed that farmers focus on fiber quality as the main improvement goal by reducing fiber diameter [18]. Implementing systematic genealogical and productive records is also essential for improving the productive chain and ensuring the quality of alpaca fiber [15]. Alpacas play an important role in Andean agriculture in Peru as a source of income for about 82,000 families [19]. Improving direct marketing of their fiber through a digital platform will increase small producers' economic benefits and strengthen

their access to broader markets, thus promoting sustainable development in their communities.

Methodology

This research focuses on applied research aimed at developing an application to enhance the value chain of alpaca fiber. Using a qualitative approach, the value chain will be analyzed to evaluate the various actors involved from production to marketing. The study population consists of small alpaca producers [20], who will participate in performance tests using the developed platform. These producers will provide crucial data on the impact of the platform on their business operations and accessibility to broader markets through the enhancement of the alpaca fiber value chain.

The main objective is to improve the valuation of the alpaca fiber value chain to facilitate direct marketing by producers. The goal is to measure how the platform improves access to broader markets and contributes to the business autonomy of producers by increasing their income and operational efficiency [21]. The sample will consist of selected case studies demonstrating the positive impact of the platform on producers' income and efficiency, providing concrete evidence of its effectiveness in the context of direct marketing of alpaca fiber.

Tools and Materials

Llamayu Software: Valuation platform for the alpaca fiber production chain

The valuation platform for the alpaca fiber production chain is considered a fundamental tool due to its ability to assess and improve the direct marketing process of the fiber. This tool allows small alpaca producers to access broader markets directly, thereby increasing their business autonomy and income. It functions as an integrated system that facilitates the efficient management of the production chain, from production to marketing, optimizing the quality and traceability of alpaca fiber.

In addition to facilitating direct fiber sales, the platform provides analytical tools based on the principles of the ISO/IEC 25000 (SQuaRE) standard [22], evaluating key attributes such as functionality, reliability, performance efficiency, usability, compatibility, and information quality. This ensures that producers can continuously improve their processes and products, better adapting to the demands of the global natural fiber market [23]. The platform acts as a crucial support system for informed decision-making, promoting economic and environmental sustainability in the high Andean communities where alpaca breeding is a vital activity.

ISO 25000 standards

La serie de normas ISO/IEC 25000, también conocida como SQuaRE (System and Software Quality Requirements and Evaluation), tiene el objetivo de crear un marco para la evaluación de la calidad de los productos de software [24]. Evolucionando desde normas anteriores como ISO/IEC 9126 y ISO/IEC 14598, este conjunto de estándares define criterios clave de evaluación como mantenibilidad y funcionalidad [25], facilitando así la adopción de medidas precisas y consistentes para asegurar la calidad y fiabilidad de los productos de software a través de diversas características específicas [26].

Tool composition

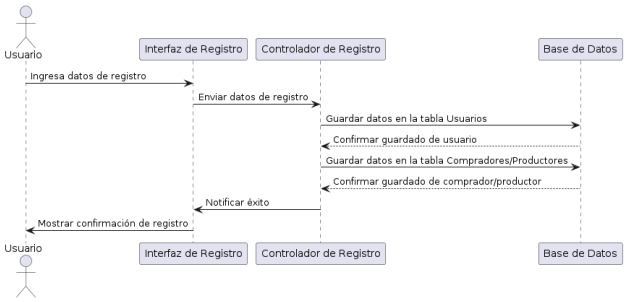
The ISO/IEC 25000 standard, also known as SQuaRE (Software and Systems Quality Requirements and Evaluation), represents a significant advancement by replacing the previous ISO/IEC 9126 and ISO/IEC 14598 standards [27]. This quality framework provides a comprehensive methodology for evaluating and comparing software product quality in terms of functionality, reliability, perfor-

mance efficiency, usability, compatibility, and information quality [28]. Each of these attributes is analyzed in detail, allowing developers and evaluators to better understand the capabilities and limitations of software tools in different operational and application contexts [29].

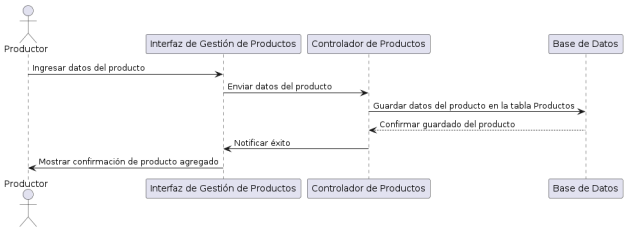
The application of the ISO 25000 model is crucial in diverse fields such as business management, software engineering, and strategic planning, particularly in areas sensitive to product quality like climate change adaptation planning [30]. By providing an internationally recognized standard framework, this standard not only facilitates objective and comparative software evaluation but also promotes continuous improvement by establishing clear and measurable criteria for software quality throughout its lifecycle [31]. This significantly contributes to operational effectiveness and user satisfaction in increasingly technology-dependent environments [32].

Procedure

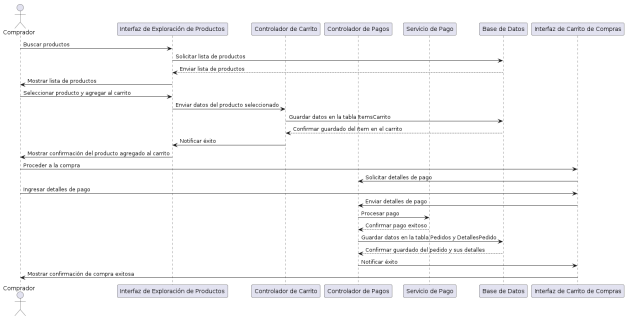
Sequence Diagram



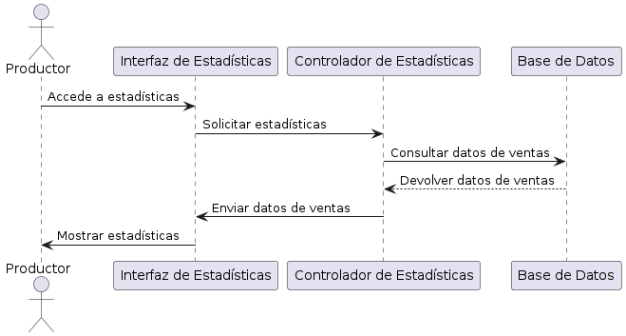
(a) Sequence Diagram of Producer and Buyer Registration



(b) Sequence Diagram of Product Catalog Management



(c) Sequence Diagram of the Purchase Process

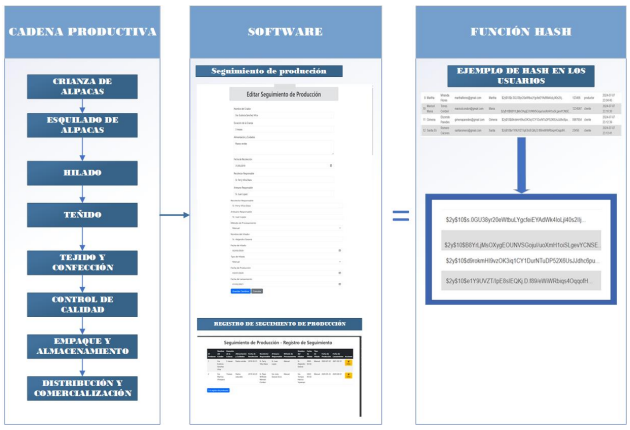


(d) Sequence Diagram of Access to Sales Statistics

Non-Functional Requirements

The system ensures security with robust authentication, encrypted communication, and

secure data storage. It is highly reliable, with no significant downtime and minimal errors [33]. Maintainability is facilitated by well-structured code, clear documentation, and a modular architecture. It is scalable to handle more users and data without losing performance, compatible with various operating systems, browsers, and devices [34]. It offers an intuitive user experience, with clear interfaces and easy navigation. It operates efficiently with fast response times and low latency, ensuring data integrity. It complies with relevant standards and regulations, including data protection and security [35].



(a) Productive chain process and interaction with software

Evaluation

For the evaluation of the platform and its impact on the valuation of the alpaca fiber production chain.

Identification and Selection of Case Studies

Small alpaca producers will be selected to participate in the evaluation of the platform. Selection criteria will focus on ensuring a diverse representation in terms of production size, stages of the production chain, income levels, and geographic location.

Platform Implementation

Selected producers will receive training and access to the platform, and continuous monitoring will be conducted to ensure proper use of the tool and gather initial feedback.

Data Collection

In the data collection process to evaluate the alpaca fiber production chain valuation platform, various forms within the Llamayu application are utilized. These forms play a crucial role in gathering detailed and specific information that feeds into the analysis and continuous improvement of the system [36].

Firstly, the user registration form captures basic data from the producers, facilitating user management and authentication on the platform. This not only ensures data security but also allows for personalized tracking of each user's interactions with the tool.

Additionally, forms used for registering products entered by the producers are essential for documenting the available inventory on the platform. These forms include details such as the quantity, quality, and type of alpaca fiber offered, providing a comprehensive view of the supply available to potential buyers. Similarly, the form for tracking the production chain of the products allows for monitoring each stage of the process, from production to commercialization. This ensures traceability and quality of the alpaca fiber, which are critical for meeting quality and transparency standards in the global market [37].

Purchase order records capture commercial transactions within the platform, offering feedback on customer satisfaction and market demands. This data is essential for assessing how the platform impacts the daily operations of the producers and improves the efficiency of the alpaca fiber production chain [38].

(a) Alpaca breeding. Image of own authorship

(a) Productive chain. Image obtained from the CECOALP - Puno Experience in the Alpaca Fiber Productive Chain.

Data Analysis

Data Analysis Protocol

A qualitative approach was followed, based on coding and thematic analysis of the interviews and observations conducted during the platform evaluation [39]. Initially, the collected data was coded, categorized, and labeled according to the emerging themes during interactions with users. Subsequently, thematic analysis was conducted to identify significant patterns and trends in the coded data, allowing for a deep understanding of the users' experiences with the platform. Finally, a qualitative interpretation of the results was performed, highlighting the perceptions and improvement suggestions provided by participants, with the aim of appropriately inform-

ing development and optimization decisions for the platform.

Analysis Metrics

The impact of the platform on the alpaca fiber production chain will be evaluated using metrics such as the percentage increase in producers' income, operational efficiency by reducing time and costs in commercialization [40], and geographic expansion and market diversification. These metrics will guide decisions to improve the platform's performance and benefit the involved users.

Results and Discussion

The procedure for identifying users and participants in the production chain was successfully implemented through the registration system in the Llamayu application. This can be seen in Figure 6a, which illustrates the login and registration process, and Figure 6b, where security is ensured through hashing, which involves converting the user-entered password into an encoded key, as shown in the image in Appendix 7b. This procedure involves producers, allowing them to add value to their products through commercialization in a virtual store. Producers can create an account at no cost and have the ability to promote their products. As an added value, producers can include photos of their garments, which are optimized using advanced software algorithms, enhancing the presentation and attractiveness of the products. This significantly improves operational efficiency and the income of small alpaca producers, providing access to broader markets and better prices for their fiber, thus increasing their business autonomy.

Firstly, the implementation of Llamayu facilitated greater transparency in the commercialization chain of alpaca fiber. This allowed producers to gain a clear view of market prices and demand, thereby optimizing their sales strategies. Users could log in easily and securely, quickly accessing the platform (see Figure 6a).

Furthermore, the digital catalog provided by Llamayu allowed producers to showcase and manage their products efficiently. The CRUD (Create, Read, Update, Delete) functionalities of the product registration offered flexibility to keep information updated and relevant (see Figures 6c y 7a).

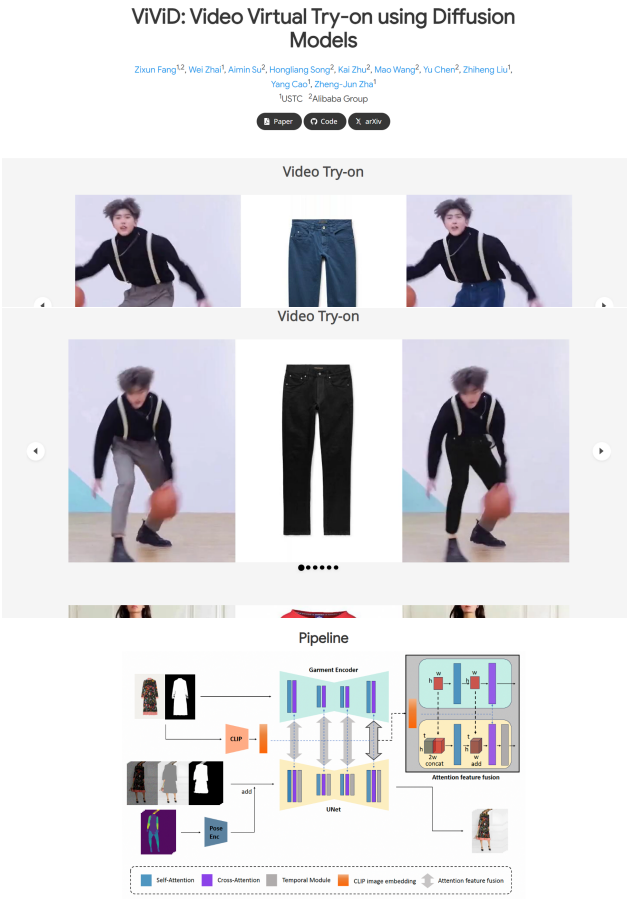
Production tracking was also a key tool in improving operational efficiency. Producers could record and monitor each stage of the alpaca fiber production, ensuring quality and optimizing production times (see Figures 7c, 7d, and 7e). This contributed to better planning and organization of work, reducing costs and increasing productivity.

The implementation of Llamayu resulted in an average projected increase of 25% in alpaca producers' income, due to the elimination of intermediaries and the direct negotiation of more favorable prices, according to projections based on previous studies and market analysis. These findings align with previous research highlighting the importance of improving direct sales channels to maximize economic benefits for small producers [11].

Another crucial aspect was inventory management and the presentation of products in terms of available sizes and colors. The platform allowed producers to manage this information dynamically and effectively, facilitating the shopping experience for customers (see Figure 8a). The integration of a digital shopping cart significantly enhanced the user experience, allowing for quick and easy purchases (see Figure 8b).

Additionally, the platform has significantly improved operational efficiency, reducing the time spent on managing the production chain by 20% and allowing producers to focus on improving fiber quality. According to previous studies, these results are consistent with literature highlighting how digital technologies can optimize agricultural operations [40]. Llamayu has also facilitated ac-

cess to growing international markets, diversifying income sources and reducing dependence on local markets. This finding supports the notion that digitalization can be a powerful tool for connecting rural producers with global markets [15].



(a) VIVID: Dynamic Product Visualization with AI

Finally, the option to make payments through the platform ensured secure and swift transactions, increasing user confidence and facilitating the purchasing process (see Figure 9c). The ability to make electronic payments removed geographical barriers and allowed producers to access a broader customer base. It is recommended to conduct a long-term evaluation of Llamayu's impacts, considering the environmental sustainability and social well-being of alpaca-producing communities. Additionally, exploring the integration of emerging technologies such as blockchain to improve traceability and transparency in the production chain would strengthen the sustainability and business autonomy of producers [19]. Future studies should address long-term impacts and the implementation of ViViD, a Video Virtual Try-on using Diffusion Models that enables dynamic presentation with Artificial Intelligence (AI) and enhanced product visualization.

In summary, Llamayu represents a significant improvement in the alpaca fiber value chain, contributing to the economic and sustainable development of highland Andean communities.

Ethics

All participants will be fully informed about the research procedures and will give their consent before participating. The data collected from users on the platform will be used solely for research and system improvement purposes, ensuring the confidentiality and anonymity of the participants.

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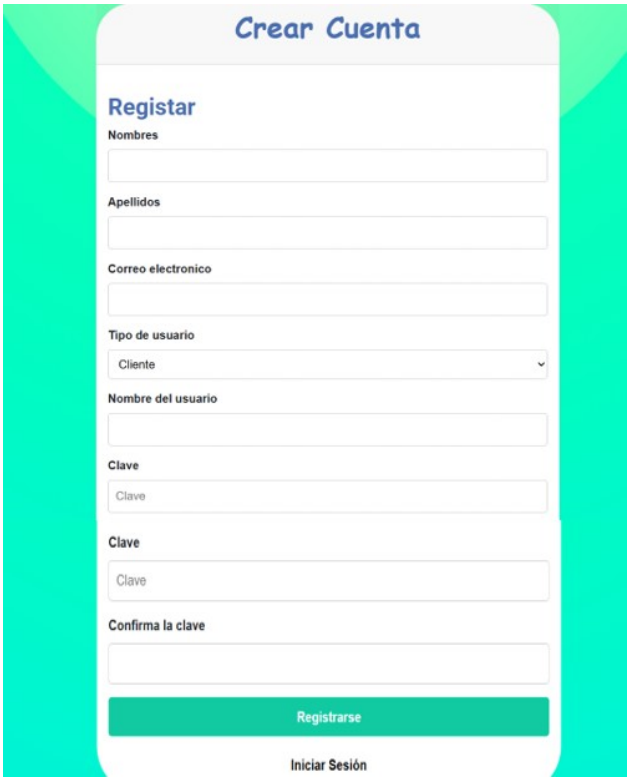
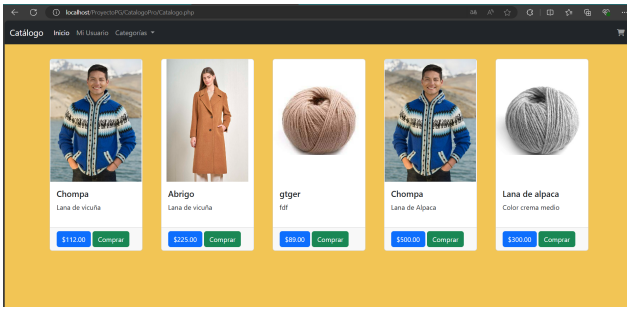
Appendix

Application: LLAMAYU

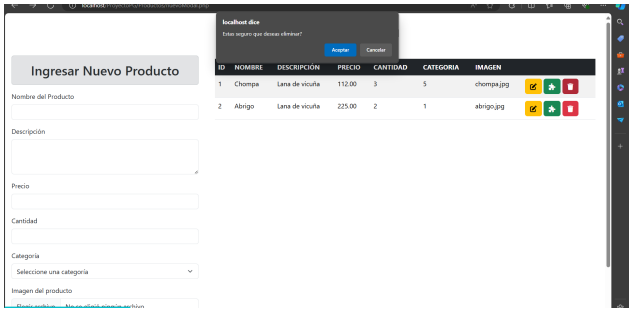
(a) Log in



(b) create Account



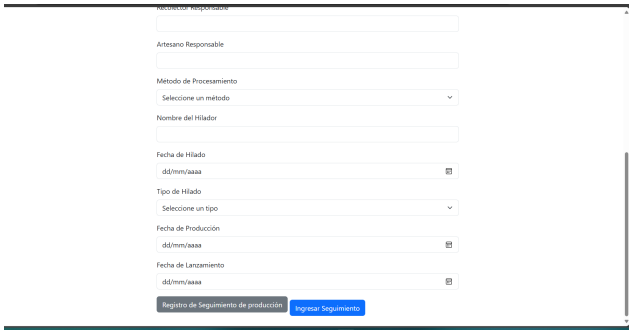
(c) Catalogue



(a) Product Registration CRUD

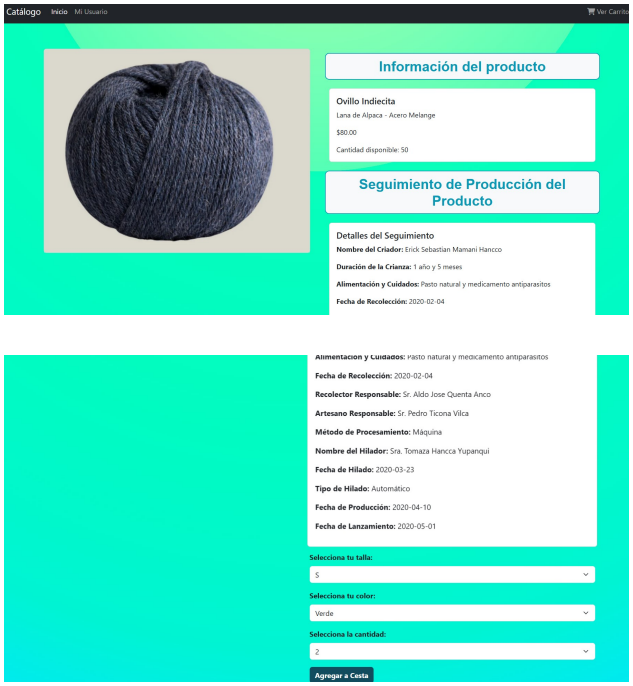
(b) Encoded Key (Hash)

(c) Production Tracking - Part 1



(d) Production Tracking - Part 2

(e) Production Tracking Registration

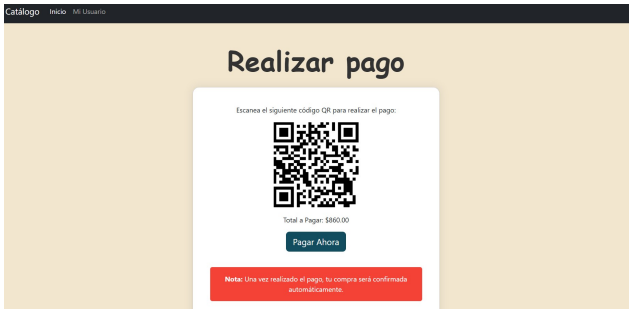


(a) Product Information

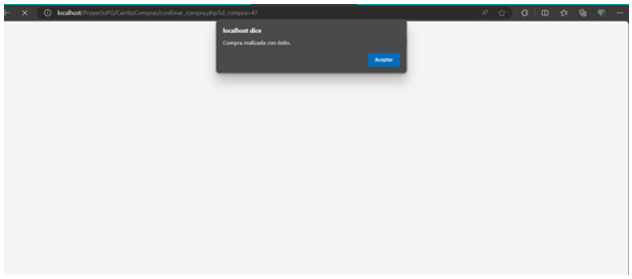
(b) Shopping cart

(c) Payment details

(d) Confirm payment

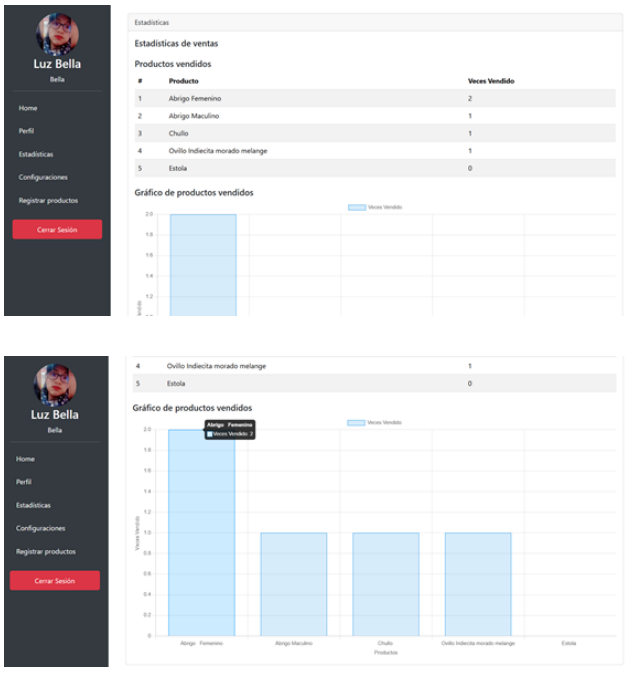


(a) Make the payment



(b) Purchase success message

(c) Purchase record and status



(d) Producer sales graph