REVIEW

DESIGNING TOMORROW'S COCOA FERMENTATION SOLUTION: A PRELIMINARY CONCEPTUAL FRAMEWORK

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Malaysian Cocoa J. 16: 15-18 (2024)

ABSTRACT – *This concept paper introduces an innovative approach to revolutionize traditional cocoa fermentation methods. It does so through the exploration of advanced design principles by incorporating the human-centered design approach. Focused on hygienic advantages of the alternative materials, enhancing efficiency and sustainability in cocoa processing, the preliminary conceptual framework establishes the foundation for a future mechanical solution. A thorough approach that incorporates design thinking and user-centered design has been adopted. The testing phase will also involve various assessments using wet cocoa beans. This iterative process allows continuous refinement based on feedback and real-world testing. It satisfies the technical specifications as well as the requirements and preferences of cocoa practitioners. This study also highlights the role of quality evaluation in understanding the influence of the mechanical cocoa fermentation box on the overall quality of cocoa beans. The anticipated outcome of this project is the creation of an innovative mechanical cocoa fermentation box. It is designed not only to meet the technical requirements but also to align with the needs and traditions of cocoa farmers, fostering a future where technology uplifts the human experience in cocoa farming while contributing to the production of premium cocoa beans.*

Keywords: Cocoa fermentation, mechanical fermentation solution, human-centered design, cocoa bean quality

INTRODUCTION

Cocoa fermentation is essential in the development of flavor and aroma in cocoa beans. Camu *et al*. (2008) and Papalexandratou *et al*. (2011) agreed that the development of flavor, aroma and color precursors in well-fermented dry cocoa beans is mostly dependent on the post-harvest curing of cocoa beans, including fermentation. Despite its importance, traditional fermentation methods which usually are using wooden boxes and natural environmental conditions are often inconsistent, resulting in variable quality and yield (Afoakwa, 2008; Schwan & Wheals, 2004). This inconsistency poses significant challenges for cocoa farmers, impacting their productivity and profitability.

This concept paper proposes a modernized solution to enhance the cocoa fermentation process, addressing current limitations and highlighting the innovative solutions. Recent advancements in product development and design thinking offer opportunities to provide an evolution to the conventional fermentation systems. By incorporating engineering principles, alternative materials and a user-centered design approach, it is possible to develop more efficient and reliable fermentation solutions to cater the needs of cocoa industry.

Currently, experts in Malaysia suggest using a three-layer wooden fermentation box for the cocoa bean fermentation. However, there are several problems associated with this conventional fermentation box. It does not appear to be elder-friendly and the inconsistent procedures required to handle it pose challenges for cocoa farmers. Therefore, this project aims to facilitate an efficient fermentation process and to assess the quality of the cocoa beans produced by the mechanical cocoa fermentation box, ensuring that the innovation does not compromise the final product.

By achieving the objectives of this study, this project is expected to provide cocoa farmers with a more reliable and effective fermentation tool, ultimately leading to premium cocoa beans and improving the economic value for the cocoa farming community.

COCOA FERMENTATION TECHNIQUES AND MATERIALS

Cocoa beans will undergo spontaneous fermentation once they are exposed to the environment. Then, they are subjected to several fermentation techniques, ranging from the most frequent heap fermentation to the usage of perforated boxes or trays that are allowed to ferment for four to seven days. (Schwan & Wheals, 2004; De Vuyst *et al*., 2010; Ganeswari *et al*., 2015). In Malaysia, Malaysian Cocoa Board recommends cocoa farmers to apply the shallow box fermentation as a standard fermentation practice. The shallow box fermentation requires five days of fermentation with one turning on the third day (Kharul, 2013). The farmers are choosing to use the shallow box fermentation with the three-layer cascade wooden box to maximize the fermentation quantity. The typical three-layer wooden fermentation box used by Malaysian farmers has a minimum total height of 140 cm. However, National Institute of Occupational Safety and Health (NIOSH) provides guidelines for evaluating two-handed manual lifting tasks, which is mainly related to the activities during the fermentation process. It is stated that the load must be lifted within the workers' power zone, which is close to the body, between mid-thigh and mid-chest height (NIOSH, 2007).

The microbial succession provides distinct characteristics to the fermentation process. Initially, yeast colonization is encouraged by the low pH and oxygen level, producing ethanol and pectinolytic enzymes. This results in a significant rise in yeast population within 24 hours, followed by a steady decline. The remaining conditions encourage the growth of lactic acid bacteria (LAB), which peak 36 hours after the fermentation started. The main activity of LAB is to degrade glucose to lactic acid. The metabolism of non-acid by-product causes the increase in overall pH levels. The LAB population declines after 48 hours of fermentation, allowing possibility of the expansion of acetic acid bacteria (AAB). The exothermic reactions of AAB increase the temperature up to about 50 °C. The reactions involve the oxidation of ethanol to acetic acid, which is then further oxidized to carbon dioxide and water. It is believed that the AAB-induced circumstances are what promote protein dispersion and hydrolysis. Thus, AAB could be essential for flavor precursor synthesis (Lima *et al*., 2011; Schwan & Wheals, 2004; Sengun & Karabiyiki, 2011). Both the biology and chemistry of cocoa bean fermentation are complex and all aspects of the process need to be subjected to comprehensive, simultaneous, dynamic analyses to quantitatively predict the outcomes of defined changes. Understanding the microbial ecology of the fermentation process is the first step in optimising the quality of end products (Schwan & Wheals, 2004; Ardhana & Fleet, 2003; Garcia-Armisen *et al*., 2010).

The use of stainless steel tanks in the food-related industry has increased in popularity due to the demand for hygienic production techniques (de Melo Pereira *et al*., 2013). Despite their advantages, maintaining optimum fermentation temperatures can be challenging because stainless steel has a reputation for having a lower thermal conductivity. Temperature is a critical factor during fermentation as it significantly influences microbial activity and enzymatic processes that develop the flavor and aroma of the cocoa beans (Afoakwa *et al*., 2008; Schwan & Wheals, 2004). However, there is a lack of research on materials with the appropriate thermal conductivity to maintain optimal fermentation temperatures. This gap highlights the need for studies focusing on innovative materials that can provide better thermal control during fermentation, ensuring more consistent and high-quality cocoa bean production.

Cocoa bean fermentation involves a complex microbial succession, making the use of stainless steel tank is a challenging potential that requires specific approaches to avoid failure. While numerous studies have focused on the fermentation process of producing high-quality cocoa beans, it remains unclear how specific microbial groups or individual species influence cocoa bean quality and chocolate character, and whether they are essential to the fermentation process (Zhao & Fleet, 2014). Despite these challenges, this research can contribute significantly to the advancement of cocoa fermentation practices. It has the potential to benefit small-scale farmers and cocoa-growing regions by improving post-harvest processing and value addition. Furthermore, the findings of this study will serve as a foundation for future research in cocoa fermentation technology and its impact on cocoa product quality.

DEVELOPING AN ALTERNATIVE FERMENTATION BOX

This concept paper proposes the development of an alternative fermentation box by integrating a user-centered design approach with the design thinking process. The user-centered design ensures that the solution is tailored to meet the specific needs and preferences of the end users, while the design thinking process provides a structured methodology to foster innovation and problem-solving. By placing the user at the center of the design process, the aim is to develop a fermentation box that not only meets the technical specifications but also aligns with the practical needs of the farmers.

A user-centered approach starts with some surveys and interviews that will be conducted with groups of farmers to gather knowledge of their current fermentation practices, challenges, and preferences. This information will be crucial in defining the user requirements for the new fermentation box, ensuring that the design addresses practical issues such as ease of use, maintenance, durability, and cost-effectiveness. This knowledge leads to the concept design phase, which translates insights from user needs and problem definitions into tangible design ideas.

The concept designs are then refined into detailed designs, which specify the exact features and functionalities of the fermentation box. The initial prototypes of the fermentation box will be fabricated and tested. These prototypes will be tested to collect any feedback on the usability, functionality, and performance. The feedback is essential for the iterative improvements to the design. During field trials, the performance of the fermentation box will be closely monitored, and data on fermentation quality and user satisfaction will be collected prior to the launch of the product.

The design thinking process consists of a few stages, which are empathizing, defining, ideating, prototyping and testing. All of these stages are important as they promote creativity, initiates various points of view, and emphasizes iterative testing and refinement. In order to fully comprehend the routines, difficulties, and goals of farmers in relation to cocoa fermentation, the first step in the empathy phase is to interact with them through observation and interviews. This phase seeks to develop empathy and collect firsthand information about their experiences. After that, the define phase examines all of the viewpoints obtained to create a concise problem statement and design specifications, highlighting the essential requirements and areas for innovation. During the ideate phase, a wide range of potential solutions and innovative materials for the fermentation box are brainstormed using creative techniques such as mind mapping and sketching to explore various design possibilities. Fabricating tangible prototypes of the fermentation box during the prototype phase involves concentrating on several design iterations that cater to the specified user needs. These prototypes are evaluated through user testing and feedback. The test phase conducts rigorous testing of the prototypes with farmers, collecting data on usability, functionality, and fermentation outcomes. Feedback from this stage informs further refinements. Finally, the design is finalized and ready for full-scale implementation. This includes creating the final version of the fermentation box, and releasing the product onto the market for commercialization.

The working procedure of this study will adhere to a planned flow of steps. In order to determine the specifications for the new fermentation box, the project will first identify the needs for the box through farmer interviews and surveys. The product development process will be guided by this data, which will result in the first prototypes being created in accordance with the specified design criteria and user input. Clear instructions on how to use the fermentation box will be included in an operating manual that will be developed. The prototypes will undergo fermentation testing and analysis to ensure quality and efficiency, followed by sensory evaluations of the fermented cocoa beans to assess the impact on flavor and aroma. Throughout the testing phases, data collection and analysis will be carried out. If the results are satisfactory, the project will move forward with final implementation and launch, with the goal of offering a creative and practical solution for cocoa fermentation.

CONCLUSIONS

This concept paper outlines a comprehensive approach to developing an alternative cocoa fermentation box through the application of design thinking and user-centered approach. The proposed solution aims to address the existing limitations in cocoa fermentation practices, specifically with regard to thermal conductivity and microbial activity, by emphasizing on user requirements and utilizing iterative prototyping and testing. This methodology not only ensures the development of a practical and efficient fermentation box but also contributes to the advancement of cocoa processing technologies. The expected outcomes include improved quality and consistency of fermented cocoa beans and significant benefits for small-scale farmers. The findings of this study will offer a strong guideline for future studies in cocoa fermentation technology with the ultimate goal to produce premium cocoa beans.

ACKNOWLEDGMENTS

The author would like to thank Malaysian Cocoa Board (MCB) for supporting this work and the Director General of the MCB for permission to publish this paper. Appreciation is extended to the staffs in MCB that were directly and indirectly involve during the preparation of this article.

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