



Safety and Oil Palm Processing Equipment: Challenges and Innovations

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Abstract: Oil palm processing is a critical component of the global agricultural industry, especially in Southeast Asia and West Africa, where it is a significant economic driver. The rising demand for palm oil has necessitated efficient, safe and environmentally sustainable processing equipment. This paper reviews the safety considerations and manufacturing technologies for oil palm processing equipment, highlighting current advancements in machine design, safety protocols, material selection, and automation while focusing on minimizing workplace hazards, ensuring equipment reliability, and enhancing productivity. The study emphasizes the need to address safety risks associated with palm oil mills, namely mechanical failures, hearing loss, ergonomic challenges, chemical pollution and environmental concerns, while comprehensively discussing the latest techniques for mitigating these risks, such as automation and remote sensing, robust material selection, computer aided design for precision, ergonomically designed workstations to mention a few. The review concludes by advocating for continuous innovation and more robust regulatory frameworks. Future direction of safety in oil palm processing will involve Artificial Intelligence for predictive maintenance while ensuring sustainability.

Keywords: Oil Palm, Safety, Fabrication, Hazards, Equipment Design.

INTRODUCTION

Oil palm (*Elaeis guineensis*) is one of the most significant sources of edible vegetable oil worldwide. Over the years, palm oil production has been significantly scaled up due to rising global demand. Apart from its domestic use as cooking oil, it also finds usability in the manufacturing of products like soaps, cosmetics, confectioneries, Margarine, and even as a source of biofuels. This development has led to the expansion and modernization of processing facilities for oil palm. However, oil palm processing equipment design, fabrication, and operation pose numerous challenges, especially regarding workers' safety, operational efficiency, and sustainability. In this context, there is an urgent need for continuous improvement in equipment fabrication and safety standards (Nguyen *et al.*, 2021). The absence of a proper regulatory framework as witnessed in many oil palm processing facilities, vis-à-vis poor ethical standard in health, environment and safety, are major contributors to occupational injuries in the sector. In developing countries practising semi-automated operations, there are documented incidences of injuries arising from non-use of personal protective equipment, equipment malfunction, and workers burnout (Udo and Etim, 2020).

Fabrication of oil palm processing equipment by local and small-to-medium scale industries increases equipment availability to smallholders at affordable rates in addition to promoting local content; however, there are concerns in the area of lack of adherence to safety standard, inadequate personnel training and expertise, and lack of access to quality materials that meets industrial safety standards (Okechukwu and Okwu, 2021). Recent studies emphasize the need to improve equipment safety, especially in oil palm mills, where workers are exposed to hazards like burns, mechanical injuries, and ergonomic stress (Smith *et al.*, 2020). The use of computer aided designs to aid precision in the equipment design processes is being embraced. Integrating advanced technologies like automation, predictive maintenance, and stronger, more durable materials, transforms how equipment is designed and fabricated (Santos *et al.*, 2020).

With improvements in ergonomic design, material quality, and also leveraging sensor technology, it has become easier to deal with safety related issues in oil palm mills. In modern set-ups, temperature and heat sensors, systems for emergency shutdown and machine guarding are deployed to minimize incidents in the sterilization process and operations involving high pressure (Adetola *et al.*, 2022). Regardless of these improvements, issues such as poverty, lack of access to up-to-date information and trends in safe oil palm processing, and a high illiteracy level especially in developing countries have hampered the widespread application across large, medium, and small-scale operators. This article explores the latest advancements in oil palm processing equipment design and fabrication, emphasizing improving safety standards and mitigating occupational hazards by adopting current technology-driven innovations, emphasizing personnel training and retraining, and strict-adherence to regulatory frameworks and policies. There is therefore the need for a multi-stakeholder approach in addressing the issues of safety and oil palm processing equipment fabrication, considering the benefits of an improved industrial safety standard as well the place of oil palm in achieving global food security and strengthening the economies of nations.

2. Safety Concerns in Oil Palm Processing

From harvesting the fruit bunches to extracting palm oil, oil palm processing involves a series of complex mechanical operations. These processes include sterilization, digesting, pressing, and clarification, all of which require heavy machinery, such as sterilizers, boilers, digesters, screw presses, and clarifier systems (Nguyen *et al.*, 2021). Unfortunately, the mechanical nature of these operations places workers at the risk of various hazards which can lead to injuries that can either be minor, or in some cases fatal. Research findings reveals that amongst Nigerian small-scale processors and semi-mechanised palm oil mill operators, several injuries abound. A study done in Delta State, Nigeria shows that arising from poor safety practices like failure to use Personal Protective Equipment (PPE), 78% of mill workers have been exposed to injuries such as burns, cuts and spikelet (Bamidele, 2015). A similar survey done in neighbouring state of Edo recorded a 100% irritation, arising from incomplete combustion with a staggering 84% and 94% injuries resulting from spikes presses, impacting negatively on workers' health and mill operations (Bamidele, 2015). Studies by Oyekale *et al.* (2015) reveals the nexus between workers exposure to hazards and a reduction in technical productivity, therefore recommending sensitization on hazard mitigating strategies to enhance productivity. Below is a list of some hazards in a typical palm oil processing mill:

2.1 Mechanical Hazards

Moving parts of processing equipment pose serious injury risks. Workers are particularly exposed during maintenance or when working near rotating machinery like digester screw presses and decanter centrifuges (Baba *et al.*, 2020). Mechanical hazards can also be pressure and explosion related, besides the effect on worker, it could have far-reaching impact like low turnover, equipment downtime, total equipment failure, and loss of revenue.

2.2 Thermal Hazards

High-temperature operations like sterilization and clarification are part of palm oil processing. Hence, equipment failures or human errors in handling hot surfaces can lead to severe burns (Joo *et al.*, 2021). Workers in the process are exposed to heat stress and heat-related illnesses like heat exhaustion and heat rashes.

2.3 Ergonomic and Physical Hazards

Tasks like fruit bunch harvesting, manual sorting, and strenuous and labour-intensive processing lead to fatigue and musculoskeletal disorders among workers (Santos *et al.*, 2020). Other possible causes include manual lifting of weighty objects, incorrect lifting posture leading to neck, shoulder and back injuries and strains. Fatigue resulting from prolonged work hours is a potential risk enabler.

2.4 Environmental Hazards

Environmental and safety concerns also emanate from hazardous by-products and pollutants such as Empty Fruit Bunches (EFB), Palm Oil Mill Effluent (POME), and carbon emissions generated from processing activities (Kumaran *et al.*, 2020). POME can sometimes runoff into water bodies, leading to loss of biodiversity. Incomplete combustion arising from poorly designed sterilizer fire chamber or use of less-combustible materials for sterilization and clarification processes can lead to severe environmental pollution and respiratory disorders.

2.5 Hearing Loss

Stages in palm oil processing like digestion and also kernel recovery stages like fibre-nut separation often exposes workers to noise levels in the neighbourhood of 98dBA to 99dBA thus exceeding the 85dBA threshold specified by the United States National Institute for Occupational Safety and Health ---NIOSH (Azodo and Onyekwere, 2023).

2.6 Chemical Hazards

A recent risk assessment analysis done by (Roslan and Md Said, 2024) on some Malaysian oil mill workers like equipment fabricators, boiler operators and laboratory crew regarding the effect of combined exposure to noise and chemical pollutants (Ototoxicants); concluded that lack of strict adherence to PPE usage and insufficient engineering controls promote hearing-related problems.

3. Fabrication Innovations for Enhanced Safety

In Recent innovations have been introduced in the design and fabrication of oil palm processing equipment to mitigate these safety challenges. These include:

3.1 Automation and Remote Monitoring

The introduction of automated sterilization, pressing, and milling systems has reduced workers' proximity to hazardous machinery (Tan *et al.*, 2020). This has invariably minimized human interventions in the process thus reducing the possibility of injuries arising from human error. An automated mill removes some lifting responsibilities from humans thereby reducing risks of ergonomic incidents. For example, sensor-based systems monitoring sterilizer temperature and pressure have helped prevent overheating and explosions.

3.2 Robust Material Selection

Utilization of new materials with improved resistance to wear and corrosion to enhance the durability and safety of equipment. For instance, using stainless steel and composite materials to construct presses and sterilizers has improved safety and operational length (Li *et al.*, 2021). Quality control is achieved through a rigorous material selection processing, ensuring that poor quality materials that could cause equipment collapse under work pressure are never used.

3.3 Ergonomically Designed Workstations

Research advancement in physical strain reduction through improved equipment and workstation design has resulted in adjustable platforms, lifting mechanisms, and ergonomic tools for sorting and pressing fruit bunches in modern oil palm mills (Zhao *et al.*, 2021). This will reduce the incidents of musculoskeletal disorders amongst workers.

3.4 Safety Mechanism in Equipment Design

Advanced safety features like interlocking mechanisms, automatic shutoffs, and emergency stop buttons have been integrated into equipment to prevent accidents and injuries (Gao *et al.*, 2022). Interlocking mechanisms prevent accidents in palm oil processing mills by disallowing operation in the event of an open or loosed guard or if an equipment is not safe to run. Modern-day systems integrate Programmable Logic Controllers which with the help of sensor technology check if conditions are safe prior to process operation.



Fig. 1 A set of Small-Scale Processing Equipment (SSPE) (www.nifor.gov.ng).

The Nigerian Institute for Oil Palm Research (NIFOR), through the Agricultural Engineering Research Division (AERD) designs and fabricates processing equipment for small scale processors and mill owners. Fig. 1. Above shows a typical NIFOR SSPE set, made up of the rotary fruit screen, fruit sterilizer, NIFOR patented Digester Screw Press --- DSP (an integrated unit for digesting the sterilized fruits and also for pressing out the crude palm oil). The set also has the clarifier for clarification of the CPO to produce the NIFOR Special Palm Oil (SPO). Improvement in design, using computer aided designs to aid precision is one of the ways of improving safety in the SSPE fabrication process.

4. Case Studies and Implementation

Several examples illustrate the successful implementation of these innovations. Improved processing efficiency and minimal exposure of workers to thermal hazards are now possible in most Malaysian mills through the integration of automated sterilizer control systems (Lim *et al.*, 2022). In Indonesia, a palm oil mill incorporated robotic arms to handle the unloading of fresh fruit bunches, significantly reducing the risk of musculoskeletal injuries among workers (Ali *et al.*, 2021). From the research conducted by (Panjaitan and Panggabean, 2022), regarding workers exposure to varying noise levels across four major oil palm processing equipment during kernel recovery, different control measures including but not limited to Engineering and administrative control, and use of PPE) were deployed to minimize noise levels during operations.

5. Regulatory Framework and Industry Standards

Besides technological innovations, safety improvements in oil palm processing equipment fabrication also require regulatory frameworks and industry standards for more effectiveness. The Malaysian Palm Oil Certification Council (MPOCC) and the Roundtable on Sustainable Palm Oil (RSPO) have established guidelines to promote safe working conditions and environmental sustainability in the palm oil industry (RSPO, 2020). Compliance with these standards has become a significant requirement for local and international companies. In Nigeria, the Standards Organisation of Nigeria (SON) ensures strict adherence to safety and construction standards in local oil palm mills in order to become SON---Certified. They also carry out certification of equipment to ensure safety of workers.

6. Future Directions

Amidst research progress, several gaps remain in improving safety and fabrication techniques. Besides the engineering, administrative control and regulatory framework in place, the future of safety in the oil palm processing will incorporate smart technology and sustainability. Ongoing research is developing more efficient automation systems, incorporating artificial intelligence (AI) for predictive maintenance, and using sustainable and biodegradable materials. (Nguyen *et al.*, 2021). Moreover, improving workers' training and fostering a safety culture in oil palm mills will be vital for long-term improvements (Santos *et al.*, 2020).

CONCLUSION

The safety and fabrication of oil palm processing equipment is critical to ensuring the welfare of workers and the sustainability of the palm oil industry. Many kinds of hazards are associated with oil palm processing and some measures are already in place to mitigate their occurrence. Additionally, advancements in automation, ergonomic design, and material technology have vastly improved safety standards in oil palm mills. However, continued innovation and robust regulatory frameworks are imperative to address ongoing challenges and ensure the industry's sustainable future.

CONFLICT OF INTEREST

There is no conflict of interest in this research review.

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