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Physical Strain and Postural Risks Assessment of Gari Processing Activities in Nigeria

Ogundele O.O, *Ajayeoba A. O., Oyetunji, O.R., Adetunji M. O., Ayinde K. J. & Oluwadare M. O.
Department of Mechanical Engineering
Ladoke Akintola University of Technology
Ogbomoso. Oyo State. Nigeria
***Corresponding Author:** aoajayeoba@lautech.edu.ng

ABSTRACT

The paper presents an evaluation of physical strain, postural concerns, and occupational dangers linked to gari processing in Nigeria. It delineates the conventional, labour-intensive processes of gari production and elucidates how these activities subject workers, predominantly women, to considerable ergonomic and health hazards, including awkward bending, repetitive upper-limb movements, prolonged standing, heavy manual handling, heat exposure, inhalation of smoke and dust, as well as burns and cuts. The paper demonstrates that numerous prevalent gari-processing postures, assessed using known ergonomic techniques (RULA, REBA, OWAS) and physiological strain assessments, are classified within medium to high-risk categories, leading to extensive musculoskeletal diseases and tiredness. It emphasises findings from many Nigerian research regarding respiratory complaints, heat stress, and injury patterns among processors. The publication emphasises the necessity for engineering enhancements, optimised workstation design, cost-effective mechanisation, employee training, utilisation of personal protective equipment, and ongoing research to mitigate health hazards and enhance safety, productivity, and well-being in the gari-processing industry. Keywords: Gari, Physical Strain. Postural Assessment, Risk, Hazards.

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1. INTRODUCTION

Gari is a roasted granular food derived from fermented cassava. Gari, alternatively spelt 'garri', is a granular, frequently toasted product derived from fermented cassava mash. It is extensively consumed in Nigeria, either as eba or soaked in water, and plays a significant role in food security due to cassava's drought resilience and affordability (Ndjouenkeu et al., 2021). Gari processing typically operates as a family or small group enterprise, with women predominantly participating in many communities, while males engage in more labour-intensive chores like as transportation and pressing. Labour is frequently informal, conducted without rigorous occupational health supervision, and processors typically function in semi-enclosed facilities or open yards adjacent to residences.

The conventional production chain is labour-intensive and predominantly conducted in informal environments (Akpoghelie et al., 2025; Udoro et al., 2014). The amalgamation of manual labour, exposure to smoke, dust, heat, and repetitive postures results in various occupational hazards, including respiratory diseases, diminished lung function, musculoskeletal disorders (MSDs), burns and thermal stress, cuts and lacerations, ocular irritation, and chemical/biological risks, such as food hygiene issues and cyanide exposure due to insufficient processing.

Research from Nigeria's academic and public health literature elucidates these issues and suggests feasible solutions (Ndjouenkeu, et al., 2021). Numerous descriptions and evaluations delineate a consistent series of unit operations employed in conventional gari production (Akpoghelie et al., 2025; Ndjouenkeu et al., 2021; Udoro et al., 2014) as follows:

i. Harvesting and transport: cassava roots collected from farms and brought to processing sites.
ii. Sorting and washing: removal of rotten roots, soil and stones, then washing.
iii. Peeling: manually with knives or small hand tools.
iv. Washing: cleaning the peeled cassava with water
v. Grating/a pulping: traditionally manual or with small electric/mechanical graters.
vi. Dewatering/pressing: mash is pressed (sacks under weights, mechanical press) to remove water and allow fermentation.
vii. Fermentation: controlled period (hours to days) in sacks or containers; reduces cyanogenic compounds and develops acidity.
viii. Sieving/crumbling: breaking up pressed cake into uniform particles.
ix. Roasting/frying (garifying): mash is roasted on open pans/plates over wood or charcoal fires to achieve final texture and moisture.
x. Cooling, grading, packaging and storage: the roasted mashed cassava paerticle are allowed to cool, then packaged

2. OCCUPATIONAL AND HEALTH ISSUES IN GARI PROCESSING

Ergonomics seeks to "adapt the job to the individual" by designing equipment, tasks, workstations, and workflows in accordance with human capacities and constraints. Bowie and Jeffcott (2016). Poor alignment of tasks with workers' physical and cognitive abilities leads to heightened muscular tiredness, acute injuries, and cumulative disorders (WMSDs), as well as diminished productivity, absenteeism, and elevated healthcare and socioeconomic expenses. Prominent occupational organisations assert that ergonomics diminishes muscular fatigue, enhances productivity, and prevents or mitigates work-related musculoskeletal disorders (WMSDs). The World Health Organisation and the International Labour Organisation advocate for ergonomic strategies in occupational health programs to safeguard worker welfare.

According to Melhorn and Gardner (2004), gari processing in Nigeria subjects workers to many health hazards, including smoke from roasting fires, dust from gari particles, heat stress, frequent burns, and injuries from manual tools. The labour-intensive characteristics of the tasks, which include lifting, peeling, stirring, and extended bending, result in prevalent musculoskeletal ailments. Substandard hygiene, insufficient fermentation, and minimal utilisation of protective clothing exacerbate chemical, biological, and physical risks. The amalgamation of these threats renders gari processing a high-exposure profession necessitating enhanced equipment, safer operational techniques, and heightened health awareness. These include the following (as shown in Figure 1):

a) Air pollution, particle matter, and respiratory health: smoke from wood or charcoal fires utilised for roasting; dust from dried or roasted gari; aerosols generated while handling and sieving. Cross-sectional studies in Nigeria indicate elevated ambient particulate matter (PM) levels near gari processing sites, correlating with a higher incidence of respiratory complaints and worse lung function among workers relative to controls. Numerous studies, report cough, dyspnoea, wheezing, and quantifiable declines in pulmonary function metrics among gari processors. These data indicate both immediate irritating effects and hazards associated with prolonged exposure(Oloyede et al., 2020).

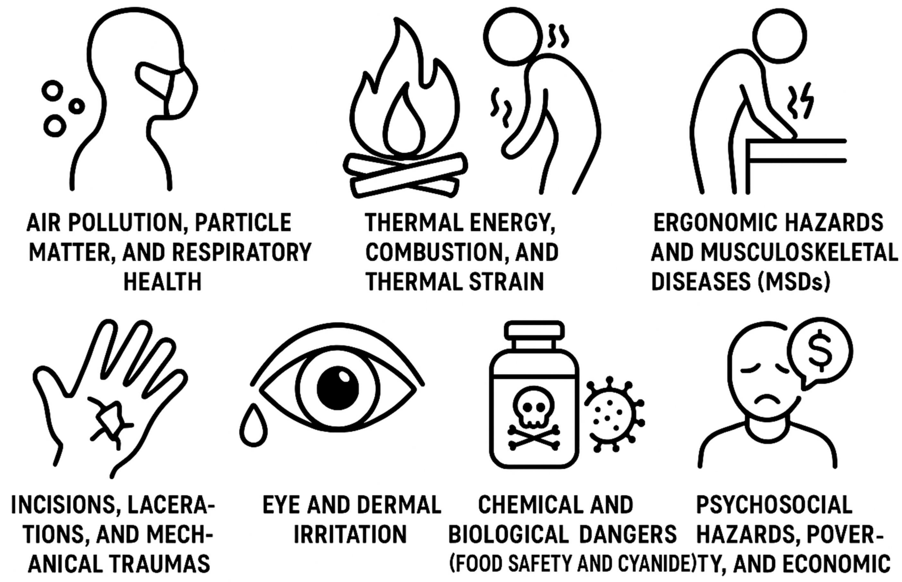

Figure 1: Occupational and Health Issues in Gari Processing

b) Thermal energy, combustion, and thermal strain: open flames, heated frying pans, splattering of hot mash or oil, and extended proximity to heat sources. Observational studies and hazard assessments indicate a prevalence of mild and occasional severe burns, thermal discomfort, and heat-related complaints during peak roasting activities. Heat stress exacerbates dehydration and exhaustion, hence heightening the likelihood of accidents (Okareh, Ogunfayo, and Atulumah, 2015).
c) Ergonomic hazards and musculoskeletal diseases (MSDs): Repetitive motions (stirring, crushing), improper postures (stooping, extended standing, bending the back during roasting or sieving), and hand carrying of heavy sacks and equipment. Ergonomic evaluations and studies from southwestern Nigeria indicate significant postural strain during gari-frying activities. Research indicates discomfort and musculoskeletal disorders (MSDs) concentrated in the lumbar spine, shoulders, and wrists; the risk is elevated in activities necessitating prolonged asymmetric postures and repetitive hand movements (Samuel and Adetifa, 2013).
d) Incisions, lacerations, and mechanical traumas: Peeling and manual grating result in knife cuts and hand injuries. Hand tools and tiny grinders lacking sufficient protection elevate the danger of lacerations. Research and field studies indicate the prevalence of minor lacerations; at numerous locations, first-aid is informal and access to timely medical assistance is restricted (Okareh, Ogunfayo, and Atulumah, 2015).
e) Eye and dermal irritation: Smoke, dust, and droplets from roasted mash provoke irritation in the eyes and skin. Eye discomfort and conjunctivitis are frequently documented among workers in smoke-laden or dusty settings. Insufficient availability of eyewear and gloves is prevalent (Okareh, Ogunfayo, and Atulumah, 2015).
f) Chemical and biological dangers (food safety and cyanide): Cassava contains cyanogenic glucosides; insufficient processing or brief fermentation may result in residual cyanide levels in the product. Effective fermentation and roasting diminish cyanide to acceptable levels; however, substandard hygiene and insufficient processing may present chemical and microbiological food safety hazards. Reviews and extension documents underscore the importance of maintaining proper hygiene in first unit operations (washing, handling) to mitigate microbial contamination (Musa et al., 2022).

g) **Psychosocial hazards, poverty, and economic stressors:** Informality, extended working hours, seasonal income fluctuations, and diminished bargaining power are social variables that combine with physical hazards. Numerous occupational hazard assessments indicate that poverty and restricted access to personal protective equipment (PPE) contribute to risk-taking behaviour, such as the refusal to wear masks due to expense or discomfort from heat (Fosu-Mensah et al., 2021).

Nevertheless, the literature and technical manuals advocate for a hierarchy of controls tailored to the informal and small-scale context:

a) **Engineering controls** encompass enhanced fuel-efficient stoves or enclosed frying pans equipped with chimneys or local exhaust systems to eliminate smoke at the source, mechanisation for grating and mechanical presses to mitigate heavy manual lifting and repetitive loading, and ergonomic redesign of frying stove height, alongside the utilisation of trolleys and lighter containers to diminish stooping and lifting burdens (Alaka et al., 2025).
b) **Administrative controls and training:** Implementation of task rotation, regular breaks, and workload management to mitigate repeated strain and heat exposure, alongside instruction in safe handling, basic first aid, and hygiene for food safety and cyanide risk management (Fosu-Mensah et al., 2021).
c) **Personal protective equipment (PPE):** Utilisation of respirators/masks (suitable for dust/smoke), heat-resistant gloves, enclosed boots, and eye protection. The practical adoption of PPE rises when it is comfortable, affordable, and culturally appropriate (Tonbra, Godwin, and Chukwuka, 2025).
d) **Public health and service connections:** Regular medical screenings (respiratory function assessments), vaccinations as necessary, and localised health education initiatives aimed at processors.

3. POSTURAL ASSESSMENT IN GARI PROCESSING

Processing cassava necessitates that postural assessment be considered an essential aspect of occupational health evaluation in gari processing. Field research addressing these tasks has utilised established ergonomic methodologies to measure exposure and propose enhancements (Samuel et al., 2010).

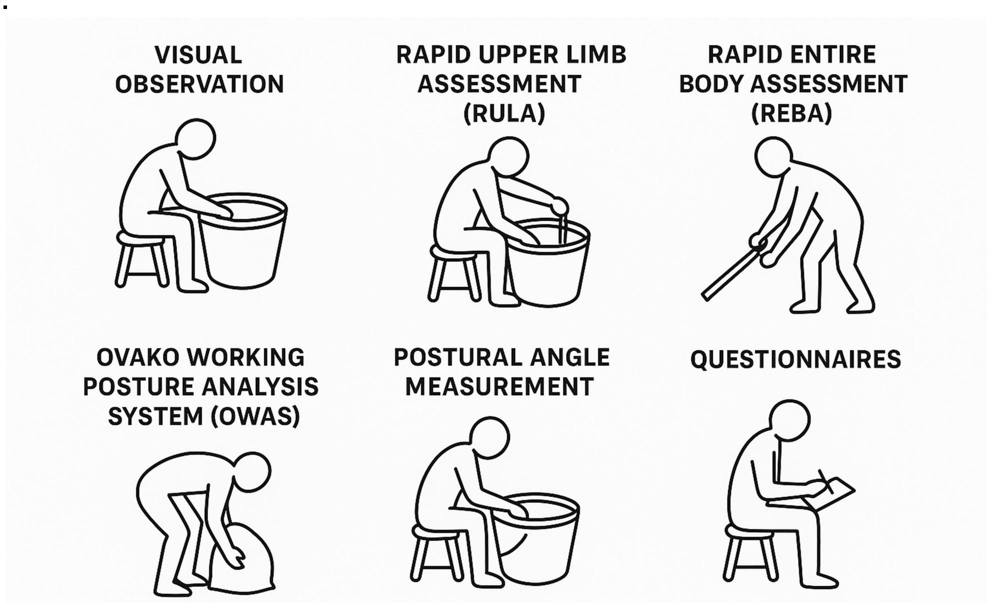

Figure 2: Postural Assessment Techniques

Postural assessment determines the body regions under load (such as the back, neck, shoulders, and wrists) and identifies the work elements (including trunk flexion, twisting, raised arms, and prolonged static posture) that contribute to this loading. Quantifying posture establishes a connection between observed task demands and reported symptoms, as well as injury risk. This is essential in contexts where clinical reporting is restricted, necessitating that exposure assessment informs prevention strategies (Samuel and Adetifa, 2013).

In informal and resource-constrained environments, postural assessment provides practical and cost-effective recommendations, such as work height adjustments, anti-fatigue mats, modified stirring implements, and scheduled posture rotation, which can be implemented without significant capital investment. The identification of ergonomic risks establishes a foundation for worker training and community outreach (Samuel et al., 2010). Postural assessment techniques (Figure 2) vary from basic visual inspection to formalised, validated scoring systems. The integration of qualitative observation, quantitative scoring, and worker surveys yields the most actionable insights.

These include:

a) Visual observation: entails the systematic monitoring (either live or via video) and documentation of worker postures, task cycles, durations, and environmental factors. The system is cost-effective, adaptable, and rapidly deployable in field environments, effective for identifying significant postural deviations (such as deep trunk flexion and extreme shoulder elevation) and recording task sequences. Observer bias, imprecise quantification of joint angles, and challenges in cross-siteA comparisons due to the absence of standardised recording sheets or video review are significant issues. Video capture for subsequent frame-by-frame analysis enhances reliability (Samuel & Adetifa, 2013).
b) Rapid Upper Limb Assessment (RULA): This tool evaluates postures, force, and repetition primarily concerning the upper limbs, neck, and trunk, yielding a score that signifies the urgency of intervention.This is beneficial for activities that involve significant loading of the arm, shoulder, and neck, along with moderate engagement of the whole body, such as stirring and repetitive hand movements.It is efficient and commonly utilised; primarily concentrating on the upper limbs, it may inadequately represent whole-body loading. Al Madani and Dababneh (2016).
c) Rapid Entire Body Assessment (REBA): REBA evaluates overall body postures, encompassing the legs, trunk, neck, and upper limbs. It considers coupling, activity, and load/force to generate a risk score.It is beneficial for tasks involving complex trunk, leg, or neck postures, lifting, or whole-body asymmetry, such as handling large pans or transferring materials. It provides a more comprehensive assessment for whole-body tasks compared to RULA, although it requires slightly more time to implement. Comparative analyses of RULA and REBA typically reveal complementary insights; employing both methodologies can effectively assess upper-limb and full-body risks. Al Madani and Dababneh (2016)
d) Ovako Working Posture Analysis System (OWAS): This system categorises full-body postures and recommends prioritised actions for tasks in heavy industry.
e) Postural Angle Measurement: Direct measurement of trunk flexion and shoulder angles from video frames, utilised in GARI studies to validate RULA and REBA scores.
f) Questionnaires: The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) and Nordic questionnaires are utilised to gather symptom reports that enhance posture scores. Samuel et al. (2009)

Numerous field studies, primarily conducted in southwestern Nigeria, have evaluated the postures of gari-frying workers through observation and various tools, including RULA/REBA, postural angle measurement, and symptom questionnaires, as detailed below:

a) **Excessive trunk flexion and forward bending** occur when workers lean significantly forward over large frying pans, resulting in trunk angles that exceed neutral by approximately 50–80° in certain measured samples, thereby increasing low-back loading (Samuel and Adetifa, 2013).
b) **Prolonged standing or awkward sitting:** Extended periods of standing and certain sitting postures, such as sitting adjacent to pans, result in static loading. Studies indicate that alternating sitting and standing postures can mitigate postural loading (Samuel et al., 2009).
c) **Shoulder and neck elevation**, along with repetitive upper-limb motion, such as stirring, scooping, and transferring, are identified as risk factors for upper-limb disorders (Samuel and Adetifa, 2013).
d) High risk in various prevalent working configurations: RULA scores in gari frying studies frequently indicate ranges that necessitate further investigation and modification (e.g., RULA grand scores of approximately 6–7 in certain postures), reflecting a medium to high urgency for corrective measures. REBA has indicated a moderate to high whole-body risk associated with specific tasks and workstations. The objective scores correspond with measured large trunk angles and documented discomfort (Samuel et al., 2009).

4. PHYSICAL STRAIN ASSESSMENT OF WORKERS

Physical-strain assessment involves measuring and interpreting physiological responses to work, such as heart rate (HR), heart-rate variability (HRV), oxygen uptake, blood pressure, and subjective exertion. This process quantifies the workload associated with tasks and the consequent impact on the worker's cardiovascular and musculoskeletal systems. Continuous wearable monitors are frequently utilised in actual workplace settings to record task-specific responses (Sammito et al., 2024). Assessment of physical strain quantifies the physiological costs associated with work, particularly in terms of cardiovascular and musculoskeletal load.

This is achieved through both objective measures, such as heart rate, heart rate variability, and oxygen consumption, and subjective measures, including perceived exertion. These assessments are crucial for identifying hazardous tasks, establishing safe workload limits, designing interventions (such as work-rest schedules, tool redesign, and job rotation), and mitigating both acute injury and fatigue, as well as long-term disease risk, including occupational cardiovascular disease. Recent systematic reviews and updated occupational guidelines highlight heart-rate-based metrics, such as relative heart rate and cardiovascular load indices, as effective and validated indicators for field assessment in situations where metabolic gas analysis is not feasible (Dias et al., 2023).

4.1 Common physical strains experienced by workers in gari processing

The common physical strain experienced by the workers (as shown in Figure 3) are:

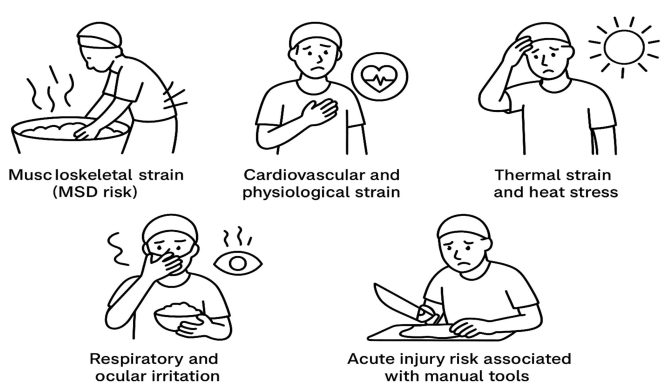

Figure 3: Common Physical Strains Experienced By Workers In Gari Processing

a) Musculoskeletal strain (MSD risk): commonly affects the neck, upper back, lower back, shoulders, and wrists. This is often due to factors such as bending, forward trunk flexion, repetitive hand movements (e.g., grating), and prolonged unsupported posture.
b) Cardiovascular and physiological strain: Activities requiring sustained effort, such as continuous sieving, carrying, and prolonged frying, elevate heart rates beyond resting levels and may result in moderate to high cardiovascular load. Heart-rate-based indices typically classify certain aspects of manual processing as moderate to heavy work (Ismaila et al., 2013).
c) Thermal strain and heat stress: Frying stages subject workers to elevated radiant heat and hot cooking fumes, resulting in increased physiological strain (elevated heart rate, sweating, dehydration) and exacerbating cardiovascular stress. Heat exacerbates perceived exertion and increases the risk of injury (Samuel and Adetifa, 2012).
d) Respiratory and ocular irritation (adjacent hazards): Smoke and dust generated from roasting and drying processes can result in coughing and eye irritation, which may decrease comfort and indirectly elevate physical strain due to diminished work efficiency and increased effort (Adenugba & John, 2014).
e) Acute injury risk associated with manual tools: Knife cuts during peeling and injuries from equipment handling are prevalent; these acute hazards exist alongside chronic strain exposures (Adenugba & John, 2014).

4.2 Relationship between physical-strain assessment results and occupational risks

Heart-rate derived metrics enable the classification of work intensity into categories such as light, moderate, and heavy, as well as the establishment of action levels. For instance, %CVL bands (refer to section D) denote acceptable, moderate, high, or intolerably high aerobic strain, which should prompt varying intervention timelines. These thresholds enable employers and occupational health professionals to convert measurements into actionable steps (Masci et al., 2022). Tasks that result in elevated working heart rates, percentage of recovery heart rate, or peak percentage of cardiovascular load are linked to acute fatigue, heightened accident risk due to diminished attention and slower response times, and an urgent requirement to decrease peak loads or cease work. Field studies in sectors such as sawmill, forestry, and construction have identified tasks with cardiac indices classified as "very heavy," necessitating prompt ergonomic or organisational modifications (Ismaila et al., 2013; Ajayeoba, 2019).

Prolonged exposure to moderate-to-high cardiovascular load over weeks to years results in cumulative stress on the cardiovascular system and may contribute to occupational cardiovascular disease. Evidence from systematic reviews indicates the significance of occupational cardiovascular exposure in cardiovascular disease risk, although causal relationships differ among studies and occupations. Nevertheless, measurement is essential for targeted prevention (Dias et al., 2023). High cardiovascular strain frequently occurs alongside demanding postures and manual handling, with combined exposures increasing risk multiplicatively. A task involving awkward trunk flexion combined with high cardiovascular load elevates the risks of musculoskeletal disorders and acute fatigue, thereby increasing the likelihood of slips, trips, and falls. Integrated assessments, which include HR, posture observation, and environmental measures, provide the most comprehensive overview for risk control (Dias et al., 2023).

4.3 Physical-strain assessment tools

%CVL, %CVS, and %RHR are the commonly used heart-rate derived indices are and they are closely related (Sammito et al., 2024).

a) Percentage Relative Heart Rate (%RHR): %RHR quantifies cardiac demand as a percentage of an individual's heart-rate reserve. Commonly utilised interpretation bands in occupational studies include: light (<20–30%), moderate (~30–45%), heavy (>45–60%), and very heavy

(>60%). The specific bands differ across studies and guidelines; it is essential to always report the cut-points utilised. Masci et al. (2022). Strengths include individualisation through the use of HRrest and HRmax, correlation with metabolic demand, and validation against oxygen uptake in numerous studies. Applicable across various tasks and personnel (Masci et al., 2022). Accurate measurement of HRmax is optimal but frequently impractical; estimation of HRmax leads to potential errors. Confounders such as heat, caffeine, emotional stress, medications, and cardiorespiratory fitness influence heart rate measures and should be taken into account (Sammito et al., 2024).

b) Percentage Relative Cardiovascular Load (%CVL): This metric is intended to represent the long-term sustainable load throughout a work shift and to inform clear operational action levels applicable in occupational ergonomics (Masci et al., 2022). Similar to %RHR, CVL is affected by environmental and individual confounders. Methodological transparency is crucial (Dias et al., 2023).

c) Percentage Cardiovascular Strain (%CVS): %CVS is typically defined in a manner analogous to %CVL, though it may employ alternative references or scaling methods. Field studies typically calculate it using HRwork, HRrest, and either measured or age-estimated HRmax. Ismaila et al. (2013) and Ajayeoba (2019). %CVS serves as an additional measure of cardiovascular burden and is utilised in conjunction with %RHR and %CVL; values across these indices should be compared to validate workload categorisation (Ajayeoba, 2019). CVS is most effective when the study offers a definitive formula and interpretation. Utilise established indices (%RHR, %CVL) for consistency across studies, unless local practices necessitate an alternative approach. (Dias et al., 2023)

5. CONCLUSION

Numerous observational and survey studies on gari-frying and other cassava processing activities (such as sieving, frying, and manual handling) indicate that workers frequently adopt a limited range of non-neutral postures (e.g., leaning forward, bending, twisting, and overstretching to access pans or sieves), resulting in significant postural loading and repetitive stress. These postures are associated with elevated RULA (Rapid Upper Limb Assessment) and other postural loading scores, indicating an increased risk for musculoskeletal disorders (MSDs) (Samuel et al., 2010). Field surveys consistently indicate that musculoskeletal complaints, including back pain, neck/shoulder discomfort, and knee/leg pain, are prevalent health issues among gari workers, especially among women who comprise the majority of the processing workforce. Complaints are linked to extended work hours, repetitive motions involved in frying and sieving, as well as manual material handling activities such as lifting, carrying, and sieving (Okareh, Ogunfayo, and Atulumah, 2015).

Research on anthropometry and workstation design reveals that existing hearths, frying pans, sieving configurations, and handling tools necessitate non-ergonomic reach distances and heights, leading to increased overstretching, trunk flexion, and awkward arm postures. In instances where enhanced or mechanised tools were tested, there was a reduction in ergonomic loads, accompanied by improvements in productivity and comfort. Olokosheet et al. (2022). Research indicates a lack of understanding regarding ergonomics among processors and a low adoption rate of protective measures; many processors depend on informal modifications, such as altering posture and utilising improvised stools, instead of implementing engineered solutions. Socioeconomic constraints, such as cost and the scale of small enterprises, restrict the adoption of enhanced tools or mechanisation. Olowogbon et al. (2021). Consequently, the following measures are recommended to enhance workers' postures and mitigate physical strain:

i. Task and work organisation (cost-effective, significant impact): Promote task rotation (alternating frying, sieving, and carrying), implement short frequent breaks, and regulate work pace to mitigate continuous repetitive strain. These measures decrease cumulative exposure even in the absence of new equipment. Ergonomic surveys and QEC/RULA assessments indicate a decreased risk associated with alterations in exposure patterns (Samuel et al., 2009). Conduct brief, focused training sessions for processors on safe lifting techniques, maintaining a neutral spine posture, and basic workstation adjustments, including stool height and pan position. Participatory methods, wherein workers contribute to the design of changes, enhance adoption (Okareh, Ogunfayo, and Atulumah, 2015).

ii. Design of workstations and tools (engineering controls): Redesign frying hearths, tables, and sieving stands to align with local anthropometric measurements, thereby minimising back and shoulder flexion. Anthropometric studies establish fundamental dimensions for the design of bench and pan heights. Adjustable stands or elevated platforms can significantly decrease trunk flexion (Okareh, Ogunfayo, and Atulumah, 2015). Utilising low-cost hoists, ramps, wheelbarrows or trolleys for the transportation of heavy sacks or containers, along with mechanical sieving or powered sieves, effectively diminishes manual handling loads. Recent studies and trials of cassava sieving and chipping machines demonstrate ergonomic and productivity advantages, with potential for scalability within cooperatives (Alaka et al., 2025). Supply lightweight, long-handled sieves and ladles featuring ergonomic grips; ensure frying pans are equipped with handles and stable bases to prevent awkward reaches and excessive force during use. Modifications to handle length and angle can decrease loading on the wrist and shoulder (Samuel et al., 2010).

iii. Community, economic, and policy measures for sustainable uptake: Establish cooperative-owned mechanised equipment, such as sieves, grinders, and chippers, to enable small processors to access mechanisation at a manageable cost. Pilot studies indicate that group ownership enhances feasibility (Alaka et al., 2025). Agricultural extension, women's microenterprise programs, and occupational health services must incorporate ergonomic assessments and practical solutions as standard components (Olowogbon et al., 2021). Facilitate small loans or subsidies for enhanced equipment and promote local production of ergonomically-designed tools to reduce costs and ensure maintainability. Local manufacturing enhances cultural alignment (Samuel et al., 2018).

iv. Monitoring and Evaluation: Employ straightforward, replicable screening instruments (e.g., QEC, RULA, Nordic questionnaire) in community health or extension surveys to monitor the prevalence of musculoskeletal disorders (MSD) and the effects of interventions. Gather baseline anthropometric data during workstation design. (Samuel et al., 2009)

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