Investigating heat stress in *gari* frying

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Abstract: One of the greatest discomforts widely reported in *gari* frying is heat stress experienced by the processors. The effects of this risk, among other inherent risks, on the workers call for detailed investigation into the cause and effects with a view to mitigating them. When excessive, this can cause heat stroke, a condition that can either threaten our lives or cause dire consequences. This study was carried out in 40 *gari*-frying workstations in Ifo Local Government area of Ogun State and its environs. Data were collected with questionnaire and oral interview, together with the use of a heat stress assessment checklist. Further qualitative analysis was done using Wet Bulb Globe Temperature (WBGT). Statistical analysis was performed using Analysis of Variance (ANOVA) to test hypothesis on the WBGT. The mean value of WBGT index recorded was 35°C, which is above the permissible WBGT of 31°C, indicating the prevalence of heat stress. The use of other low level but more effective source of heat has been recommended, such that workers would have less contact with heat during the frying task.

Keywords: heat stress, *gari* frying, wet bulb globe temperature index, check list, ergonomics

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1 Introduction

Climate in the work environment is an important factor in determining the physical comfort satisfaction of workers, and their comfort affects job satisfaction and performance. There are four primary variables that define climate, namely air temperature, humidity (relative humidity), air movement and radiation from surrounding objects including the sun. The most comforting working environment seems to be in the temperature range between 19℃ and 26℃ at a relative humidity of 50% and slow air movement about 0.2 m/s. The four variables strongly affect not only the comfort level of workers, but also their physical well-being. Heat balance is required as the body faces debilitating and sometimes fatal consequences when the body deviates from its normal value of 37℃. When environmental conditions cause body temperatures to rise above or fall below normal, there is a risk of either heat stress or cold stress.

Heat stress occurs when the body takes in and/or produces more heat than it gives off, thus raising the core body temperature according to the thermal balance equation.

$$\Delta HC = M - E \pm R \pm C - W \quad \text{(kCal or kJ)} \quad (1)$$

where, ΔHC = net change in heat content in the body (heat gained or lost); M = metabolic energy produced; E = heat lost through perspiration and evaporation; R = radiant heat loss or gain; C = heat loss or gain by convection; and W = work performed by the body.

Equation (1) indicates that the body temperature can increase due to various combinations of the high air temperature (which reduces convection heat loss), high humidity (which reduces evaporation from sweating), high radiation heat input, high energy expenditure (due to physical workload), and high metabolism (metabolism increases as body temperature rises – the metabolic rate increases about 10% for every 1℃ rise in body temperature). The increase in metabolic rate generates

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additional body heat, raising the body temperature further. The potential result is an out-of-control cycle that feeds itself which can be fatal.

Heat stress can result in many forms of illness including heat rash in which areas of the skin erupt into red or white bumps due to inflammation of the sweat glands; heat cramps which are spasms of the muscles used in manual work (or other physical activity), and associated with low salt due to sweating; heat exhaustion which is also associated with low salt and whose symptoms include weakness in the muscles, nausea, dizziness, and fainting; and heatstroke (the most severe of the illnesses) which is a serious failure of the body's thermal regulatory system characterized by high fever, dry skin, collapse, and sometimes convulsions and coma. In extreme cases, it may result in death.

The body's cardiovascular system and sweat glands operate to relieve heat stress. The cardiovascular response is to dilate the blood vessels in the skin and to increase the heart rate, which together have the effect of increasing blood flow from the heated internal regions of the body to the external skin areas. Perspiration produced in the sweat glands removes heat by evaporation. Various approaches can be used to reduce the incidence of heat stress in the work environment.

Cassava processing is highly labour-intensive in this part of the world due to the crudeness of the methods used, as it is carried out at an artisan level (Oloko et al., 2006). In Nigeria, cassava tubers can be processed into several kinds of products such as *fufu*, *gari*, cassava flour for bakeries, cassava flour for livestock, chips and *pupuru*. The products listed above all share similarities in the production techniques including peeling, washing, grating or crushing and drying.

Methods used in the production of *gari* vary from one location to another, but there are similarities. Oloko et al. (2006) investigated the status of *gari* processing in Ondo state Nigeria where they summed it up to include harvesting, transportation, peeling, washing, sorting, fermentation, sieving, tempering and bagging. Adeyemo et al. (2006) examined the existing cassava processing in Southwestern Nigeria covering Ogun, Edo and Anambra states, and categorized them into two types, namely white and yellow – for the white type, processing steps include peel, wash, grate, press, sieve and fry (Anambra method); peel, wash, grate, ferment, dewater, sieve and fry (Edo method); peel, wash, grate, ferment, dewater and fry (Ogun method). For the yellow type, peculiar to Edo, these include peel, wash, grate, oil, grate and fry.

Garification (*gari* frying) which is a process consisting of simultaneous dehydration (drying) and cooking could be observed in two phases (following falling and constant rate drying phenomenon) and this also informs the regulation of the heat supply accordingly. This includes the initial phase when much heat is supplied and little stirring (after spreading all over the pan) is required to get the water removed; the final phase when less heat is required and much stirring is required in order to prevent the mash from caking and burning. The heat intensity in the course of frying affects the quality of the product. The moisture content of dewatered and sieved cassava mash is between 50% and 65% which has to be reduced to about 12% after the frying operation (Igbeka, 1995). The frying operation was observed to involve two processes namely starch gelatinization of the particles and drying.

Igbeka (1995) noted discomforts due to heat and the sitting posture of the operator. He put the fuel efficiency of the process as less than 10%. Raw materials Research and Development Council (RMRDC – 2004) also discovered that the task exposes them to heat, smoke and cyanide fumes. The challenge is to improve the workplace under which the task is performed to reduce the inherent hazard on the job.

A workplace is characterized by an interaction between the following parameters: the worker (with attributes of size, strength, range of motion, intellect, education, expectations and other physical/mental capacities); work setting (comprising furniture, parts, tools, control/display panels and other physical objects); a work environment (created by climate, lighting, noise, vibration and other atmospheric qualities). The interaction of these parameters determines the manner by which a task is performed and the physical demand of the task. As the physical demand of the task increases, the risk of injury also increases. When the physical demand of a task exceeds the physical capabilities of a worker, an injury is likely to occur. Certain characteristics of the work settings have been associated with injury. These work characteristics are called risk factors and are divided into task physical characteristics and environmental characteristics. These include awkward posture, repetitive stress injury, long duration, heat stress, etc. (Ergoweb).

Heat stress occurs when the body's means of controlling its internal temperature starts to fail. Besides air temperature, factors such as work rate, humidity and clothing worn while working may lead to heat stress. Therefore, it may not be obvious to a person passing through the workplace that there is a risk of heat stress**.** The body reacts to heat by increasing the blood flow to the skin's surface, and by sweating. This results in cooling as sweat evaporates from the body surface and heat is carried to the surface of the body from within by the increased blood flow. Heat can also be lost by radiation and convection from the body surface.

Someone wearing protective clothing and performing heavy work in hot and humid conditions could be at risk of heat stress because: sweat evaporation is restricted by the type of clothing and the relative humidity of the environment. Heat will be produced within the body due to the work rate and, if insufficient heat is lost, deep body temperature will rise. As deep body temperature rises the body reacts by increasing the amount of sweat produced, which may lead to dehydration. Heart rate also increases which puts additional strain on the body. If the body is gaining more heat than it can lose, the deep body temperature will continue to rise. Eventually it reaches a point where the body's control mechanism itself starts to fail. The symptoms will worsen the longer they remain working in the same conditions.

When carrying out a risk assessment, the major factors to be considered are: work rate – the harder someone works the greater the amount of body heat generated; working climate – this includes air temperature, humidity, air movement and effects of working near a heat source; worker clothing and respiratory protective equipment – may impair the efficiency of sweating and other means of temperature regulation; worker's age, build and medical factors – may affect an individual's tolerance. (Health safety executive)

Heat stress could be assessed qualitatively using; Heat Index (HI), Humidex, Tropical Summer Index (TSI), Discomfort Index (DI) and Wet Bulb Globe Temperature (WBGT) (Mansoureh, 2011). The Wet Bulb Globe Temperature (WBGT) is a composite temperature used to estimate the effects of temperature, humidity, wind speed and solar radiation on humans. The WBGT index was proposed in order to avoid the elaborate procedure of determining the Effective Temperature Index (ET)[2] which was an empirical index derived from a series of laboratory studies around 1920 that became the established method used to evaluate heat stress (Parsons, 2006). According to Parsons (1999 and 2006) the assessment of hot environments can be done using a simple method based on the WBGT (wet bulb globe temperature) index which is provided in ISO 7243. If the WBGT reference value is exceeded, a more detailed analysis can be made (ISO 7933) involving calculation, from the heat balance equation, of sweating required in a hot environment and predicted heat strain.

Although the prevalence of heat during the *gari*-frying process has been observed in related studies (Igbeka, (1995); RMRDC (2004)) and various strategies have been evolved to control heat generated during this process, the heat risk involved in this task has not been studied to establish the risk involved.

This study, therefore, aims at establishing the inherent heat stress in the *gari*-frying task with a view to proffer a solution to the problems or to mitigate them.

2 Methods

A survey was carried out in 40 *gari*-frying workstations, selected by purposive sampling, in Ifo Local Government area and its environs in Ogun State Southwest of Nigeria. The investigation of the heat stress was carried out in three stages which are; physical evaluation, quantitative assessment and qualitative analysis.

For the first stage of the investigation, the workstations were visually inspected to identify the heat source and to check if the workers wore personal protective clothing or equipment. Also, the workers were interviewed, in addition to filling out questionnaires. From the questionnaires, the workers rated the level of discomfort experienced due to the heat in the work environment on a scale of very high, high, moderate, low and very low.

Very high: The discomfort experienced due to heat is highly unbearable.

High: The discomfort experienced due to heat is unbearable.

Moderate: The discomfort experienced due to heat is bearable.

Low: The discomfort experienced due to heat is insignificant.

Very low: No form of discomfort was experienced.

For the quantitative assessment, an ergonomic checklist for heat stress was used. Various parameters (factors) (Radiant temperature, Humidity, Air temperature, Clothing, Air velocity and Work rate) which contribute to heat stress were assessed using this check list. Each of these parameters was described and was given a risk score. The higher the score, the higher the risk that the parameter may contribute to heat stress. The summation of the scores would prompt the need for a qualitative analysis. If more than three parameters score more than one, then it can be said that there could be a risk of heat stress. This checklist is available at: http:// www.hse.gov.uk/temperature/information/heatstress/ riskassessment.pdf.

The qualitative analysis was performed using Wet Bulb Globe Temperature (WBGT), to determine the level of heat stress an operator is subjected to. An approximation conversion table by U.S Bureau of Meteorology was used in determining the WBGT. This table does not take the variation in the intensity of solar radiation or of wind speed into account, and assures a moderately high radiation level in light wind conditions. This conversion table was formulated from the simplified formula;

$$WBGT = 0.567T_a + 0.393e + 3.94 \quad (2)$$

where, Ta = Dry bulb temperature, ℃; e = Water vapour Pressure, hPa.

$$e = \frac{rh}{100} \times 6.105 Exp \frac{17.27T_a}{237.7 + T_a} \quad (3)$$

where, rh = Relative Humidity, %.

Source: www.bom.au/info/thermalstress

The conversion table makes use of temperature and relative humidity to determine the WBGT. The wet bulb temperature, dry bulb temperature and relative humidity for the work environment were measured and used on the table to identify the prevailing WBGT. From IS0 7243, heat stress occurs when WBGT≥31℃.

Statistical analysis was performed on the resulting WBGT using Excel 2003 (Analysis Tool Pack) to test the hypothesis based on the following criteria:

H_o: the period (workstation) the measurements were taken had no significant effect on the values collected (results obtained)

H_i: the period (workstation) the measurements were taken had significant effect on the value (results obtained).

Decision: Accept H_0, if $F_{tab} < F_{cal}$, that is, the treatment has no effect on the parameter of interest. Hence H_1 is rejected;

Accept H_1 if $F_{tab} > F_{cal}$, that is, there is significant difference in the treatment with respect to the parameter of interest. Hence H_0 is rejected.

where, F_{tab} is the variance ratio from the table at 5% while F_{cal} is the variance ratio calculated by the software.

3 Results and discussion

Table 1 shows the assessment of the workers' heat rating during the *gari*-frying task obtained from data collected through questionnaires. 85% of the respondents complained of feeling hot during the frying process, of which 75% rated the heat level as very high, and were exposed to this level of heat for a minimum of four hours. This revealed that most workers complained of the high level of discomfort due to heat during *gari* frying.

Table 1 Worker's heat rating as experienced during *gari* frying

Heat rating	Number of workers
Very Low	0
Low	1
Moderate	6
High	4
Very High	29

The Mean Score of the Heat Stress Factors (Parameters) using Heat Risk Assessment Checklist is as shown in Figure 1.

This result reveals the following phenomenon:

a) The air temperature is hot which, according to Luginbuhl et al. (2008), can lead to heat related deaths.

b) The heat source surface feels very hot to touch and may burn the skin. This was confirmed as some of the experienced workers have heat burns on their hands.

c) The humidity of the work environment is in-between very humid and very dry i.e. 45%-55%.

d) Cotton is the major clothing material of the workers.

e) The work environment is hot with still air.

f) The work rate is moderate which mainly involves the movement of the hand and arm.

Since there are more than three scores that are greater than 1, then heat stress could be present depending on the result of the qualitative analysis. This quantitative assessment clearly indicates that the major cause of heat stress in *gari* frying is the radiant heat from the heat source.

	SCORES									
Heat stress factors	-3	-2	-1	0	1	2	3	4	5	6
Air temperature					SAFE LIMIT		×			
Radiant temperature								×		
Humidity						×				
Clothing						×				
Air velocity							×			
Work rate						×				

Figure 1 Result of heat stress checklist in *gari* frying

For the qualitative assessment, the relationship between the measured relative humidity and the ambient temperature gives the result indicated in Figure 2. This shows that there is a positive correlation between the two variables. It also reveals that the environment of a typical *gari* frying station has an ambient temperature of 33℃ and relative humidity of 63%. This condition will make the worker experience some level of discomforts.

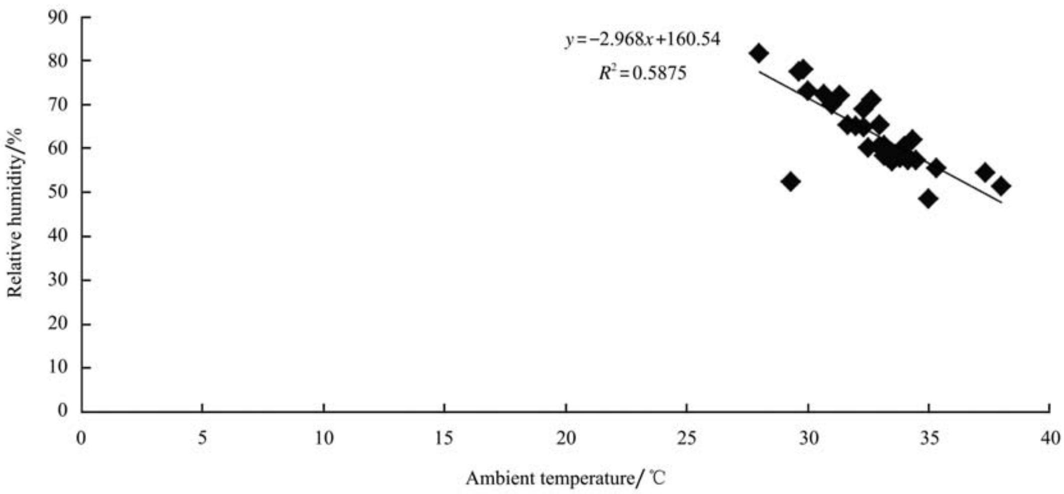

Figure 2 Relationship between the relative humidity and the ambient temperature in *gari* frying workstations

Also, the average wet bulb temperature of the work environment was 27-45℃ which, according to Jan (1999), requires a maximum exposure time of around 180 min. This further shows the extent at which the workers are exposed to intense heat, since they spend around 4 h before the fire place frying *gari*.

The measured temperature and relative humidity for different workstations gave rise to the varying WBGT as depicted in Figure 3. This reveals that there is heat stress in *gari* frying, given the mean value of 35℃, which is above the permissible WBGT of 31℃.

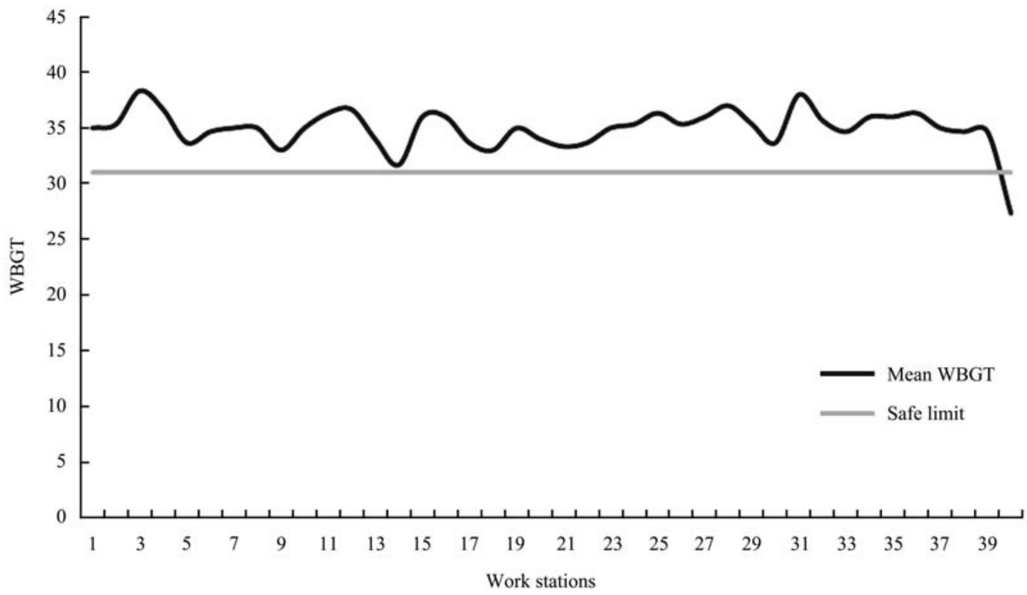

Figure 3 Mean WBGT scores for different work stations during frying

According to Nag et al. (2007), the tolerance time can be calculated from:

$$\text{Tolerance time (min)} = 1841e^{-0.103WBGT} \quad (4)$$

This gave an estimated tolerance time of 50 min; implying that anything further than this will lead to excessive discomfort. Nag et al. (2007) further added that men and women farmers at different age groups will have wider application in avoiding heat illnesses and disorders in agriculture when the tolerance limit is optimized.

The result of the hypothesis test using ANOVA in Table 2 indicates that there is significant differences between the indices for different workstations at $F_{cal} < F_{tab}$. The Null hypothesis is, therefore, accepted. This implies that there was no significant difference in the treatment and method used in measuring the WBGT between the different workstations.

Table 2 Analysis of variance for WBGT

Source of Variation	*Sum of Square*	*Degree of Freedom*	*Mean Square*	F_{cal}	F_{tab}
Between Groups	2.066667	2	1.033333	0.275148	3.073763
Within Groups	439.4	117	3.755556		
Total	441.4667	119			

Hence the results of both quantitative and qualitative analysis indicate that there is heat stress in the *gari*-frying task. Some visual observation also confirmed this result. All the workstations under investigation were open shed and none of the respondents wore any personal protective clothing or heat-conserving clothing. Rather, they either wear light clothing or are half-naked, just with underwear. Profuse sweating was also observed, especially after the early morning and before evening.

These results further revealed the need for adjustments in the traditional method of frying *gari* as reported by Igbeka (1995) and McNeill (2005). These adjustments should be ergonomic based modifications which will tend to remove totally or reduce the extent of exposure to heat experienced by workers involved in *gari* frying.

4 Conclusion

Both quantitative and qualitative heat assessment of the *gari*-frying process indicate the prevalence of heat stress. This is indicative of the fact that the workstations are all open shed with the processors usually light clothed with underwear. It is, therefore, recommended that heat insulation materials should be used in roofing the *gari*-frying workplace and the chamber should be efficiently ventilated with good air circulation to convey the heat away from the workstation. Better low level, but effective source of heat should be used for heat supply, while the workplace should be redesigned for processor to have less direct contact with heat. The processor should; take break in cool areas, work during the cool part of day, frequently drink cool water and go for regular medical examinations.

Finally, it is also recommended that an improved *gari* fryer should be designed and constructed with the following features so as to reduce the risk in the entire process:

1) A chimney to carry away the fumes.

2) At least two air inlets into the heat chamber.

3) A seat with back rest with dimensions resulting from an anthropometric survey of the population under study.

4) A well ventilated environment.

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