Ergonomic Characteristics and Mean Anthropometry Data of Gari-Frying Population in South-Western Nigeria

Olokoshe, A.A[1], Samuel T. M[2], Adegbite S.E[1], Aremu O.O[1], Fagunwa A.O[1], Onu L.I[1], Asiru W.B[1]
1. Dept. of Project development and Design Federal Institute of Industrial Research Oshodi (FIIRO), Lagos, Nigeria
2. Dept. of Agricultural and Mechanical Engineering, Olabisi Onabanjo University, Nigeria
* Email of the corresponding author: bimbola.olokoshe@gmail.com

Abstract
Disregarding ergonomics in designing a workstation has been identified as a major cause of inefficiency, low productivity and injury to personnel, especially among indigenous food processing operators. Operations such as gari-frying require an ergonomic workstation but due to unavailability or insufficient data, this has not been possible. This study focused on the collection of anthropometric data of the gari-frying population in the six southwestern states of Nigeria to provide data needed for designing gari-frying facilities that fit the target population. Twenty-five body dimensions were measured among 120 *gari*-frying processors from six states. Statistical analysis was performed using the SPSS package. Results show that there is a statistically significant difference in variability of data across and within the states in all the body dimensions measured at $P \leq 0.05$, therefore. This work, thus recommended that the workstation should be designed with percentile values to cover a larger number of the target population.
Keywords: Ergonomic, Workstation, *Gari*-frying, Design to fit, Anthropometry.
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1. Introduction

Gari *(Manihot spp.)* is slightly sour-tasting gelatinized granular flour which can either be whitish or yellowish. It is made from fresh cassava tubers and is commonly consumed in the Western part of Africa. *The processing of gari involves several unit operation*s such as peeling, washing and grating, fermentation, dewatering, pulverizing, sieving, and frying. *Gari*-frying (*Garification)* which is about the last operation in *gari* production and, to a large extent, the determinant of the final product involves simultaneous cooking and dehydration, that is, heat treatment of dewatered cassava mash, which has been pulverized into grains, to produce the gelatinized and dried granules known as *gari*.

A typical traditional gari frying work station usually comprises a container for wet cassava mash, a chair for operators comfort, a frying pan, a paddle or stirrer for turning cassava mash in the frying pan, a gari collection bowl and a fireplace. The garification process is a long and tedious unit operation involving the processor, usually a woman, maintaining a position while she continuously rigorously stirs the wet cassava mash for even distribution of heat, uniform cooking and frying. This process is done for 30 minutes for a known mass of wet gari until properly dried gari is obtained. Thereafter another batch of weighed mass of wet gari is dried and the batch drying process is continued. During this operation, it was observed that different postures were maintained by the processors to provide a bit of comfort and to improve productivity. However, most of the improved traditional garification equipment developed has been abandoned by the intended end user. This was because the majority of the developed equipment does not consider appropriate ergonomics in their designs and do not see the various equipment used as an integral part of the gari work station. The discomfort of the operator, the heat, the sitting posture required and smoke disturbance has been of concern to researchers. A close examination of the existing improved traditional garification equipment and work station in Nigeria shows that none is yet to fully satisfy all the criteria identified by Kepner *et al.,* (1978) According to them, agricultural machines must be rural integrated, simple, easy to handle and at an affordable cost for an average farmer. They should also be easy to maintain by the operators within the available farm power, or at worst the most available nearest farm power resources and they should enhance retention of quality of desired processed products.

To effectively design affordable and sustainable technology that will not only increase the productivity of rural gari processors but also improve their health, morale and general well-being, there is a need to determine the anthropometry data during garification. Anthropometry involves the systematic measurement of the physical properties of the human body, primarily dimensional descriptors of body size and shape (ANTHROPOMETRY definition (linguazza.com)).

Designers and human factors specialists incorporate scientific data on human physical capabilities into the design of systems and equipment. Human physical characteristics, unlike those of machines, cannot be designed. However, failure to take into account human physical characteristics when designing systems or equipment can place unnecessary demands and restrictions upon personnel, meeting ergonomic design goals can only be accomplished by considering the potential human user. Ergonomists must therefore understand anatomy, physiology, and human factors issues to design a product for human use. Anthropometry measurement can be taken directly or indirectly using several devices such as anthropometry boards, tape rules, non-stretch tapes, stadiometers etc. to measure the body parts. This is followed by relevant calculations; principles and rules of thumb which are applied in implementing the data for an ergonomic design. Direct measurement involves measuring the respective body part that will be used for each task to be performed in a static position. On the other hand, indirect measurements are usually taken by photographic methods using still photography and filming the whole body and/or parts from different angles against a marked grid background, or superimposition of a grid on the photographed human body. As standard practice, the collection of body structural data in static body positions (direct measurement) is easier than the collection of body functional data in dynamic body positions. When these dimensions are taken in standing static posture, it is called standing static anthropometry (Shaksat, Virtual lab, Indian Institute of Technology, 2014).

This work responds to the concerns of researchers on the discomfort encountered by rural gari processors during garification by taking the anthropometry data of gari processors in six states of the South Western part of Nigeria. The data generated is aimed at developing equipment for gari frying operations that will be easy for the processor, safe for the processors' health and with increased efficiency and productivity which will impart positively on the processors' health and invariably output and income. This study, therefore, studies how the posture adopted by gari frying population in South Western Nigeria affects the final output from the gari frying operation by generating anthropometry data and fitting the result obtained into gari frying facilities for use in designing gari frying work station with ergonomic considerations.

2. Methodology

Anthropometric measurements of 120 subjects, selected by random sampling and actual gari fryers in the processing centres, were taken in the six southwestern states of Nigeria (Lagos, Oyo, Ogun, Osun, Ondo and Ekiti states), following standard measurement procedures. The age of the population under study ranged from 17 to 65 (mean = 42.23 years; SD = 12 years). Women are most active in this enterprise; hence they were respondents in this research. Their consents had earlier been sought before taking the measurements. Table 1 depicts the anthropometric dimensions taken. The instruments used included a vernier calliper, stadiometer, measuring tape and folding rule. Each body dimension was measured three times and the average is taken to ensure reliability. The subjects selected did not have any physical deformity or handicap.

Table 1: Anthropometric Definition of Parameters Measured

S/N	Anthropometric Dimension	Definition
1	Shoulder Height (SI)	The vertical distance from the sitting surfaces to the uppermost point on the lateral edge of the shoulder with the subject sitting erect
2	Sitting Height	The vertical distance from the sitting surface to the top of the head. To measure, the subject sits erect, looking straight ahead, with the knees at right angles.
3	Stature	The vertical distance from the floor to the top of the head (vertex). To measure, the subject stands erect and looks straight ahead
4	Thigh Clearance (SI)	The vertical distance from the sitting surface to the top of the thigh at its intersection with the abdomen
5	Waist Depth	The horizontal distance between the back and abdomen at the level of the greatest lateral indentation of the waist; (if this is not apparent, at the level at which the belt is worn).
6	Popliteal Height (SI)	The vertical distance from the floor to the underside of the thigh immediately behind
7	Knuckle Height	The vertical distance from the floor to the largest knuckle of the middle finger, where the finger meets the palm (metacarpal-phalangeal joint of digit 3)
8	Knee Height (SI)	The vertical distance from the floor to the uppermost point on the knee. To measure, the subject sits erect with his knees at right angles
9	Hip Breadth (SI)	The maximum horizontal distance across the hips when seated. To measure, the subject sits erect, knees and ankles supported at right angles; knees and heels together.
10	Handbreadth at metacarpal	The maximum breadth across the hand where the fingers join the palm. To measure, the right hand is extended straight and stiff with the fingers held together.
11	Hand length at index	The maximum distance between the back and palm surfaces of the hand at the knuckle (metacarpal-phalangeal joint) of the middle finger where it joins the palm of the right hand when the fingers are extended.

S/N	Anthropometric Dimension	Definition
12	Forearm-forearm breadth	The horizontal distance from the tip of the right elbow to the tip of the left elbow
13	The eye height (SI)	The vertical distance from the sitting surface to the lateral (outer) corner of the eye (ectocanthus
14	The eye height (ST)	The vertical distance from the floor to the lateral (outer) corner of the eye (ectocanthus).
15	Hand thickness	The depth of the hand was measured transversely from the level of the middle portion of the palm to the opposite surface.
16	Elbow rest height (SI)	The vertical distance from the sitting surface to the bottom of the right elbow
17	Elbow height	The vertical distance between the floor to the radiale
18	Forward grip height (SI)	The vertical distance from the centre or a cylindrical rod fully grasped in the palm which is horizontally raised forward at shoulder level to the shoulder blade while sitting.
19	Lumbar height Grip span	The vertical distance from the centre or a cylindrical rod fully grasped in the palm which is horizontally raised forward at shoulder level to the shoulder blade while sitting.

2.1 Preliminary Survey

Information on the selected subjects was collected through questionnaires, oral interviews, personal observation and direct anthropometry data measurement during visits to the processing centres. Some major parameters were observed in each data collection centre, namely processor characteristics, workplace characteristics and socio-economic characteristics.

2.1.1 Processor characteristics

The processor characteristics observed include the number of persons at a frying point, number of hands in use and posture at the fireplace, and position of other working tools.

2.1.2 Workplace characteristics

Observed workplace characteristics include whether the location was enclosed, parameters relating to the effectiveness of the frying pan concerning shape, size and number of frying containers as well as smoke control mechanism.

2.1.3 Socio-economic characteristics

Socio-economic characteristics observed include ownership of business venture, willingness to transfer business to their children and ward, the profitability of the business Ownership of working tools, stations and farms as well as ease of getting raw materials.

Sitting in Front (SIF) **Sitting Beside (SB)**

Standing (S) **Alternate Sit Stand (ASS)**

Fig 1: Different Postures of Subjects during Gari Frying Operation and their Work Stations (Samuel, 2011)

The output in each method was measured and converted to kg/8hr-day, (Aiyelari and Alabadan 1997) Production data collected was rated as average production per day.

2.2 Anthropometric Data of Subjects

The height and weight of the subjects were measured. For the height, a metal stadiometer, graduated in centimetre, designed for this purpose, was used. With light clothes on, barefoot and heads uncovered, the subjects were made to stand erect with the back touching the metal scale and the sliding perpendicular pointer made to rest gently on the head of the subjects. Their heights were read off the scale. Three replications of each measurement were taken and the average was recorded. In the same manner, the weights were measured using a weighing balance (Hanson, Model: H89 Light Green), graduated in kg and lb. Subjects' weights were read off the scale in kilograms, as they stood erect on the machine with light clothes on(regular work clothes). Three replications of each measurement were taken and the average was recorded. Other body dimensions were taken with a tape rule, vernier calliper and folding rule. A chair of a known dimension and a platform on which to place the chair were used for the measurements requiring a sitting position. The chair platform is imperative judging by the uneven terrain of the environment. The ages of the subjects were elicited from the circulated questionnaire. Each body part was measured in triplicate to guide against errors and the average recorded. Data are collected for the subjects when they are sitting in front (SIF), sitting beside (SB), standing (S) and at alternative sit stand postures by their respective workstations. The data collected were analysed using descriptive and inferential statistical analysis with the aid of SPSS 20 software. The descriptive analysis and frequency distribution were carried out. This involved the determination of the following: mean, standard deviation, minimum and maximum values. To satisfy the different population targets workplace designers would have, different percentiles (2^{nd}, 5^{th}, 25^{th}, 50^{th}, 75^{th}, 95^{th} and 98^{th}) were calculated for the data.

3. Results and Discussion

Table 2: Variations in the Ergonomic Characteristics of the gari-frying population in Southwestern Nigeria

Features	**Processors characteristics**			**Workplace characteristics**	**Heating process**		**Estimated output kg/8hr**
Type	**No of operators**	**No hands used**	**Posture**	**In/outdoor**	**Frying medium (shape/size)**	**Smoke control mechanism**	
1	1	single	SB	Outdoor	Circular	chimney	40
2							60
3					Trapezoid (Med)	Not provided	145
4	2				Trapezoid (large)	Low wall shield	250
5	1		SIF	Indoor	Trapezoid (Med)	Chimney and enclosed	135
6				Outdoor		Not provided	150
7		both	Standing		Trapezoid (Large)		220
8			ASS				230

Table 2 shows the results of the processors and workplace characteristics which depict the postures observed in the southwestern states of Nigeria and correlates with the reports of Samuel and Adetifa (2013). These are SIF (Sitting In Front), SB (Sitting Beside), S (Standing) and ASS (Alternating Sitting and Standing). For some of the postures some processors use their two hands to stir the cassava mash, this produces more yield. Of particular interest is the ASS data which has the highest yield. This shows that the processor has higher stamina and could produce more using both hands to process. Also, alternating between sitting and standing positions improves the efficiency and productivity of the operator according to Samuel (2011) .This posture also corresponds to the ergonomic guidelines of ISO (1998) that stipulate change of posture (such as alternating between sitting and standing) for workers performing tasks for long periods, to avoid static work. ASS posture, therefore, satisfies this guideline as confirmed in this analysis.

***Socio-economic characteristics*:** From the oral interviews and analysis of the questionnaires from the processors it was deduced that the majority are hired hands or labourers employed to fry gari and about 35% are actual business owners who have their farms and process cassava from their farms. Most of the processing centres have off-takers for their produce and about 40% sell the processed gari in local markets. They all complained of pain in the waist, back, neck and wrist and some other health challenges like coughing and frail health. From further oral investigations, most of the processors are unwilling to continue with the job and do not wish their children or wards to follow in their steps because of the hardship, stress, low income and inherent health hazards involved. It was deduced further that the best sitting location is sitting in front (SIF) with the use of both hands as this gives the processor a good view of the gari being fried with adequate arm reach and less burden is exerted on the hands.

Table 3: Anthropometry of *Gari*-frying Workers in Southwestern Nigeria (All dimensions in centimetres except Age & Body Mass)

Factors Measured	Mean	S.D	Min	Max	Percentiles						
					2	5	25	50	75	95	98
Age (yrs.)	42.4	12	18	67	18	25	35	40	50	63	65
Weight (kg)	63.4	17	38	126	38.4	43	50.1	60	74.6	93	107.9
Height	156.8	5.8	141	170	144	146.1	153	157	160	166	168.7
Shoulder Height (SI)	54.9	2.0	49	59.5	50.4	51.1	53.6	55	56	58.1	59.1
Eye Height (ST)	144.8	5.7	132	160	132.4	134.1	141	145	149	154	156.9
Eye Height (SI)	67.1	3.7	58	76.9	58.5	60.1	65	67.4	69.1	73.4	76.2
Forward Grip Reach (SI)	68.5	3.7	60	77	60.7	62	67	68.5	71	74.5	75.8
ForwardGrip Reach (ST)	67.3	3.4	52	75.1	60.8	62.3	65.1	67.4	69.2	72.2	74.6
Sitting Height	78.1	4.0	61	87.4	69.5	70.2	75.9	78.4	80.9	83.4	86.7
Buttock-Popliteal Length	49.2	3.0	41	56.7	41.8	44.9	47.2	49.1	51.1	54.5	55.9
Buttock-to-Knee Length	58.2	3.2	50	66.8	50.7	52.3	56.1	58.2	59.9	64.1	66.0
Popliteal Height (SI)	40.0	3.2	34	59.4	35.3	36.1	38.1	39.8	41.6	45.3	48.2
Knee Height (SI)	50.7	2.6	41	58.4	44.6	46.1	49.2	50.9	52.4	54.8	55.8
Thigh Clearance	13.4	2.2	7.4	18.9	9.1	10.1	11.9	13.2	14.9	17.8	18.6
Forearm Breadth	43.0	5.5	29	59.8	31.6	35.2	39.4	42	46.7	52.6	56.1
Waist Depth	26.2	3.1	12	34.2	18.4	21.5	25.0	26.2	27.5	32.1	33.7
Elbow Rest Height (SI)	18.0	3.1	12	39.6	12.8	14.3	16.1	17.7	19.3	22.1	23.8
Knuckle Height	74.3	60	60	725	61.4	63	67	69	71.2	74	76.2
Elbow Grip Length	35.0	1.7	28	38.8	31.3	32.4	34	35.1	35.9	37.7	38.6
Hand Length	10.5	0.8	8	12.6	8.5	9.1	9.9	10.5	11	11.9	12.4
Hand Breadth at Thumb	9.3	0.5	8	10.7	8.32	8.6	9.0	9.4	9.8	10.2	10.4
Hand Breadth Knuckles	6.9	0.6	5.5	9.1	5.66	6.0	6.6	6.9	7.3	8.0	8.3
Hand Thickness	4.2	0.4	3.2	5.2	3.37	3.6	4.0	4.2	4.5	5.0	5.1
Grip Span	3.0	0.3	2	3.93	2.17	2.5	2.78	3.0	3.1	3.6	3.9
Hand Length at Index	17.4	0.9	15	20	15.5	16	16.8	17.5	18	18.8	19.8
Lumbar Height	16.7	2.8	11	22.6	11.23	11.9	14.4	16.9	18.4	21.4	22.3

The table above shows the mean anthropometry data and the respective percentile values of the gari-frying population of South-western states of Nigeria, to design to fit a workstation for the target population the appropriate percentile value should be applied as the result shows that across the states there are varying dimensions. The result indicates that a workplace designed based on anthropometric data from another population (even in the same location) will not be ergonomically suitable for the target population.

Conclusion

From the data generated, it is apparent that the anthropometry measurement varies even within a target population The result indicates that a workplace designed based on anthropometric data from another population (even in the same location) may not be ergonomically suitable for the entire target population. Therefore to design an ergonomic workstation and tools, the anthropometry of a representative number of the end users has to be taken into consideration. The percentiles representative of the best fit used in designing tools in the workstation should capture a large portion of the target group.

The information provided in this paper will help in solving problems of fit in respect of the *gari*-frying working population as it presents data that can be used in designing an appropriate *gari*-frying workplace in each of the six southwestern states of Nigeria with its attendant safe operation of workers and higher productivity which could not have been without it.

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