Development of Anthropometric Data Essential for Development of Appropriate *Acha* Harvesting Machine for Female Farmers in Plateau State of Nigeria

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ABSTRACT

Harvesting *acha* (*Digitaria species*) has continued be a major challenge for *acha* famers. Harvesting the crop is currently by traditional method which is time consuming and expensive. Whereas Regular combines have been used to harvest most other cereals, they are not easily adaptable to *acha* harvesting due to its unique grain characteristics, and appropriate harvester suited to the characteristics of the seeds are not available due to want of design data. An essential consideration in the development of an appropriate harvester is its ergonomics. Women form the majority of farmers involved in *acha* harvesting and should be considered in the development of an apprpraite harvesting machine. The objective of this study was to develop an anthropometric data necessary for the development an appropriate harvesting machine for *acha*. Twenty five women from *acha* producing region were selected at random in the age range of 20 to 60 years. Ten different body dimensions were measured using a nylon measuring tape. Simple means, Standard Deviations and Percentiles for each dimensional element was determined from data collected. Result obtained showed that the standard deviation of all the body dimensions measured, with the exception of circumference at the waist was low, and the difference between the 95th and 5th percentiles, 3rd and 1st quartiles and between Mean and Median were negligible. The study concluded that the means obtained are fair and true representations of the body dimensions of the agricultural women in the *acha* growing regions of Plateau State, Nigeria and recommended the use of these data for design of appropriate *acha* harvesting and other pedestrian controlled machines.

1.0 INTRODUCTION

Food insecurity has been a major challenge for most African nations, Nigeria inclusive. A major contribution to this menace is the level of production of some of the crops consumed, leading to low income for the farmer. The goal of every crop production activity is to maximize

profit with minimal input. Onwualu *et al*. (2006) explained that large scale production of crop can only be achieved with the use of machines for such operations as land clearing, tillage, planting, fertilizer application, plant protection and harvesting. Large scale production implies that fields which otherwise would be left bare and exposed to environmental degradation would be covered and protected. Crop residue from harvest of large fields goes to decrease soil bulk density there making the soil more production (Tanam, 1994) as a result of aeration and free root movement (Tanam and Babatunde, 1995). Futhermore, there would be an increase in the organ matter content of the soil, leading to an improved environment due to the cycling of plant nutrients, as inferred from Wachter and Reganold (2014).

Acha (*Digitaria Specie*) is a cereal crop whose production is predominantly in Plateau State of Nigeria, being world's highest producer. Figure 1 is the map of Nigeria showing *acha* producing region. This region includes Jos South (on latitude 9º 48′ 00" North and longitude 8º 52′ 00″ East), Bokkos (on latitude 9º 18′ 00" North and longitude 9º 00′ 00″ East), Barkin Ladi (on latitude 9º 32′ 00" North and longitude 8º 54′ 00″ East), Mangu (on latitude 9º 31′ 00" North and longitude 9º 06′ 00″ East), Pankshin (on latitude 9º 20′ 00" North and longitude 9º 27′ 0″ East), Bassa (on latitude 9º 56′ 00" North and longitude 8º 44′ 00″ East) and Riyom (on latitude 9º 38′ 00" North and longitude 8º 46′ 00″ East).

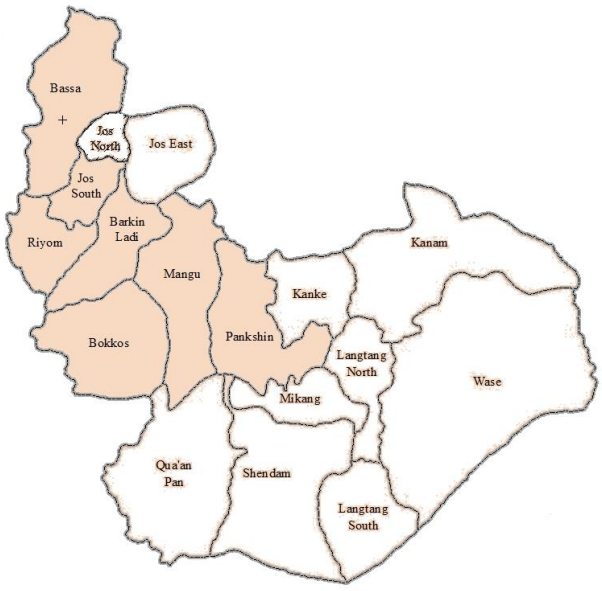

Figure1: Map of Plateau State showing Acha Growing Region (Shaded)

Acha production is still considered very low when compared with other cereals. This is attributed to the fact that no aspect of its production is known to have been mechanized (Philip and Itodo, 2006). Philip and Itodo (2006) and Cruz (2004) reported that the plant is usually harvested by cutting the stock with a knife or sickle and tied into small sheaves. To achieve timeliness, the farmer must involve his family and friends (Jideani, 1990). This explains the reason for the high cost of production, and hence, high market price of *acha*.

Increasing productivity per farm worker and alleviating the drudgery associated with manual farm work are two major objectives of mechanisation. Harvesting *acha*, among other operations, is still being done by the traditional manual methods, due largely to non availability of appropriate harvesting machines. Several machines exist for harvesting cereal crops. The ergonomics of these machines are directed toward the anthropometry of the regions they were developed. Developing machines without consideration to the well-being of the operator of the machine is a major reason for non acceptance of such machines. Performance and efficiency are influenced by the overall well-being and comfort of the operator.

Most of the machines fabricated in developing countries are done by artisans without consideration of the anticipated end users. Philip and Tewari (2000) reported that most of the tools developed in India are left to the skills and imaginations of the artisan to determine their dimensions and shapes. This leads to non standardisation of these machines and in turn, leads to their ineffective use due to induced strain on the muscles and discomfort of the operator. Where anthropometric dimensions are considered, they are done for the region where the machines are developed. Nkakini *et al* (2008) concluded that applying ergonomic data from other countries in Nigeria cannot produce the comfort, convenience, safety and efficiency desired of a farm worker. As a result of the variations in human body dimensions with region

Philip and Tewari (2000) in their study, focused on a specific region of the Nigeria. Onuoha *et al.* (2012) further explained that within the same region, body dimensions vary with gender. Philip and Tewari (2000) therefore emphasised the need to take into consideration anthropometric parameters of gender in the design of farm machines. This is further supported by Ali and Bello (2013) in their study of sorghorm threshing, showing a variation in productivity owing to tools used. Although there are no recorded statistics of men/women involvement in *acha* farming in Plateau State of Nigeria, observations in most *acha* producing areas showed that women may be more dominant.

The objective of this study therefore was to develop an anthropometric data of female farmers in *acha* producing areas of Plateau State as a precursor to the development of an appropriate *acha* harvesting machine.

2.0 MATERIALS AND METHODS

Ten (10) body dimensions of twenty-five (25) women selected at random from *acha* producing region of Plateau State of Nigeria were measured, with representatives from five of the seven Local Government Areas (LGAs) in the study region. The women were between within the age bracket of 20 years and 60 years The body features measured are indicated in Figure 2. All dimensions were measured with the aid of a nylon measuring tape. Simple means, Standard Deviations and Percentiles for each dimensional element was determined.

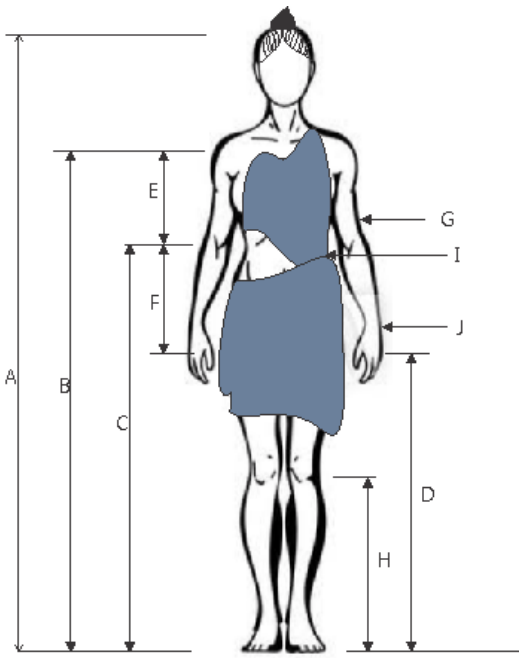

Figure 2: Parts of Female Body measured

Key to body dimensions measured

A	Height	F	Knuckle to Elbow
B	Shoulder Height	G	Circumference at Biceps
C	Elbow Height	H	Knee Height
D	Knuckle Height	I	Circumference at Waist
E	Elbow to Shoulder	J	Circumference at Wrist

3.0 RESULTS AND DISCUSSION

Table 1 is the statistical summary of anthropometric data presented in appendix A. It shows the means, standard deviations and percentiles of the various body dimensions measured. The relatively low standard deviation of all the body dimensions, with the exception of that for circumference at waist, shows that the means are fair and true representation of the body dimensions of the agricultural women in the *acha* growing region of Plateau State, Nigeria. Using these means for design purposes is therefore justifiable. This is further justified by the negligible differences between the 95^{th} and 5^{th} percentiles, and between 3^{rd} and 1^{st} quartiles as well as between Mean and Median.

Elbow height above the ground was found to be 100.8 cm while shoulder height was 132.1 cm. Developing a harvesting machine with handle as high as 132.cm would certainly not be appropriate for female farmers in the region as this would create undue strain in the upper arms. An appropriate handle level must be lower than 100.8 cm, that is, below the elbow, but higher than 68.2 cm, the knuckle level. For convenience of handling and controlling the machine in a relaxed manner the machine handle should be designed in such a way that when the operator's knuckles are on it the arm is not fully stretched. The distance should therefore not exceed 35.6 cm. The overall height of the machine should be such that the operator can see the frontend of the machine, bearing in mind the observed height of operator (155.4 cm).

Table 1: Summary of Anthropometric Data of Female Farmers in Plateau State (cm)

			Percentile				
Feature Measured	Mean	SD	5^{th}	25th	50th	75th	95th
Height	155.4	7.7	143.3	149.9	155.4	160.0	162.6
Shoulder Height	132.1	6.6	124.5	127.0	132.1	137.2	141.7
Elbow Height	100.8	4.8	94.5	96.5	101.6	101.6	108.7
Knuckle Height	68.2	3.3	63.5	66.0	68.6	68.6	71.1
Elbow to Shoulder	35.8	2.1	33.0	33.0	35.6	38.1	38.1
Knuckle to Elbow	35.6	3.4	33.0	33.0	35.6	35.6	42.2
Circumference at Biceps	27.4	3.0	23.4	25.4	27.4	27.9	33.0
Knee Height	47.4	3.3	43.2	45.7	45.7	48.3	50.8
Circumference at Waist	85.4	17.7	71.6	73.7	76.2	86.4	129.5
Circumference at Wrist	17.9	2.0	15.2	15.2	17.8	20.3	20.3

It was difficult comparing these results with values from other regions because data available for other regions from literature measured different body dimensions with the exception of height, showing similar values. For instance, to provide data necessary to design machine seat for operaotors, Nkakini *et al,* (2005) obtained values shown in table 2.

Table 2: Anthropometric data for farm workers in Nigeria (Dimensions in mm except weight, kg)

Dimensional Elements	5th Percentile	50th Percentile	95th Percentile	Difference btw 95th and 5th Percentile	Standard Deviation
Standing height	1540.00	1650.00	1800.00	260.00	77.20
Body Weight	598.00	651.00	774.50	176.50	60.50
Seat Height	400.00	450.00	504.50	104.50	82.10
Seat Depth	430.00	450.00	514.00	84.00	28.30
Seat Breadth	300.00	320.00	360.00	60.00	19.40
Elbow Rest Height	150.00	180.00	224.50	74.50	23.50
Shoulder Seat	500.00	540.00	620.00	120.00	33.90

Source: Nkakini *et al,* (2005)

There was no distinction between gender in the data presented by Nkakini *et al*, 2005. Similar data were reported by Mganilwa *et al* (2003) cited by Nkakini *et al,* (2005). These were for males in Tanzania, United State of America and India and summarised in table 3.

Table 3: Average Anthropometric data for Farm Workers in Nigeria, Tanzania, USA and India (mm)

Country	Average value of 5th percentile	Average value of 50th percentile	Average value of 95th percentile	Difference btw 95th and 5th Percentile	Total Average
Nigeria	559.71	605.85	685.57	312.24	540.84
Tanzania	566.38	639.32	732.79	152.11	522.65
USA	645.56	630.00	817.50	171.82	566.22
India	535.66	684.25	752.16	216.50	547.14

Source: Nkakini *et al,* (2005)

A comparison of the data with those obtaioned in this work would produce baised results. In like manner, Onuoha *et al* (2013) measured dimensions of feet and head in order to design protective wears for the feet and head of workers. Again there would be no basis for comparison with data for this research which are meant for the desgn of a pedestrian controlled machines.

4.0 CONCLUSION

None consideration of the anthropometry of the human operator of a machine leads to inefficiency and low productivity due to the induced discompfort, physical and emotional stress on the human. Anthropometric information is therefore critical in the development of harvesting machines, especially those to be operated by women. This would lead to increased *acha* field cultivation with its attendant environmental sustainability.

Want of design data has been responsible for the nonavailability of machines for harvesting *acha*, especially in Plateau state of Nigeria where women may form the majority in *acha* harvesting as observed. From engineering standpoint therefore, any machine development for harvesting *acha* must take women into consideration in its design to avoid injury. The dimensions and operating parameters of such a machine must be accommodating for the women. The values of the body dimensions measured should serve as guide in the machine design.

It is therefore recommended that the data reported in this study be used for the design of mechanical *acha* harvesting machine to be used mosthly by women in the *acha* producing region of Plateau State, Nigeria, with other ergonomic factors in consideration.

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APPENDIX A

Anthropometry of Women Farmers

Anthropometry of Women Farmers (cm)

SNo	A	B	C	D	E	F	G	H	I	J
1	162.56	134.62	101.6	71.12	38.1	38.1	33.02	48.26	93.98	17.78
2	170.18	144.78	109.22	76.2	38.1	43.18	25.4	55.88	81.28	17.78
3	165.1	129.54	101.6	71.12	33.02	38.1	25.4	45.72	71.12	15.24
4	162.56	142.24	109.22	71.12	38.1	43.18	27.94	48.26	86.36	17.78
5	157.48	124.46	99.06	60.96	33.02	35.56	27.94	43.18	88.9	17.78
6	162.56	134.62	101.6	68.58	38.1	30.48	25.4	45.72	88.9	15.24
7	160.02	139.7	106.68	68.58	38.1	33.02	33.02	48.26	129.54	20.32
8	134.62	132.08	96.52	68.58	35.56	33.02	27.94	45.72	73.66	17.78
9	152.4	129.54	101.6	68.58	33.02	35.56	25.4	50.8	76.2	15.24
10	149.86	129.54	93.98	63.5	33.02	35.56	22.86	48.26	73.66	15.24
11	157.48	124.46	96.52	63.5	33.02	33.02	25.4	43.18	86.36	15.24

12	162.56	139.7	96.52	68.58	35.56	33.02	27.94	45.72	73.66	17.78
13	147.32	124.46	101.6	71.12	33.02	35.56	25.4	50.8	76.2	17.78
14	149.86	137.16	106.68	68.58	38.1	33.02	33.02	48.26	129.54	20.32
15	152.4	132.08	96.52	68.58	35.56	33.02	27.94	45.72	73.66	20.32
16	152.4	129.54	101.6	71.12	33.02	38.1	25.4	43.18	71.12	17.78
17	154.94	127	106.68	68.58	38.1	33.02	33.02	48.26	129.54	20.32
18	157.48	134.62	96.52	68.58	35.56	33.02	27.94	45.72	73.66	20.32
19	147.32	124.46	101.6	66.04	38.1	38.1	30.48	48.26	93.98	15.24
20	142.24	121.92	109.22	66.04	38.1	43.18	25.4	55.88	81.28	15.24
21	160.02	132.08	96.52	68.58	35.56	33.02	27.94	45.72	73.66	17.78
22	157.48	144.78	93.98	63.5	35.56	35.56	22.86	45.72	73.66	20.32
23	149.86	124.46	96.52	63.5	33.02	33.02	25.4	43.18	86.36	20.32
24	154.94	127	96.52	68.58	35.56	33.02	27.94	45.72	73.66	17.78
25	162.56	137.16	101.6	71.12	38.1	35.56	25.4	50.8	76.2	20.32