Characterisation of small scale feed mills in a developing country

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Abstract: In most developing countries, there are numerous small scale animal farms which are sustained by the existence of small scale feed mills. The growth of these small scale feed mills is affected by some problems. A study to characterise small scale feed mills was conducted using Ibadan, Oyo State, Nigeria as a case study. 10 feed mills were randomly selected and investigated while 30 workers were assessed. The characteristics of the feed mills were investigated in terms of capacity, number of workers, unit operations, equipment used, power source, energy utilization pattern and workplace safety/hygiene. It was discovered that the average capacity of the small scale feed mills was 2.87 t/d with an average of six workers. The workers were predominantly men between 15 and 26 yr. The maximum manual, liquid fuel and electrical energy available to the small scale feed mills were 92.64 MJ/d, 1092 MJ/d and 435.24 MJ/d respectively. It was also discovered that 162 kJ of energy was used to produce 1kg of animal feed whose energy content was above 17 MJ. Other characteristics identified include; high cost of power, high rodent infestation, dirty and dusty mill environs, etc. This study exposes some problems of small scale feed milling requiring qualitative study.

Keywords: Livestock feed, capacity, energy content, energy use, unit operations

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1 Introduction

The manufacturing of livestock feed involves the transformation and combination of different raw materials with diverse physical, chemical and nutritional composition into a homogenous and standardized mixture required for stimulating an anticipated nutritional response in the animal fed. Figure 1 depicts the general systems associated with a typical feed mill. Raw materials, such as whole grains and soft stocks (i.e., minerals, salt, and other bulk non-grain materials) are metered, grinded, conveyed and then mixed. This mixed feed can be pelleted or packaged and delivered in bag form.

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Milling scale can be determined by the quantity of output, size of plant, the number of plants installed and the technique of production adopted by the producer. According to Wesley (2005) milling scale can be classified into:

1. Large and very large: These are mills with capacity over 4 t/h
2. Medium: Their capacity is between 1-4 t/h
3. Small: They operate between 100 kg to 1 t/h for village level processing or as a small commercial mills operating at 100 to 500 kg/h.

Several attempts have also been made to define and characterize a small scale industry. Ogechukwu (2011) and Ogunkoya and Aderoba (2010) identified small scale industries to have: a small number of workers; low annual business turnover; local areas of operations; minimal sales volume; relatively minimal financial strength; relatively small market; many in number than large scale industries; etc. Small scale production of feed

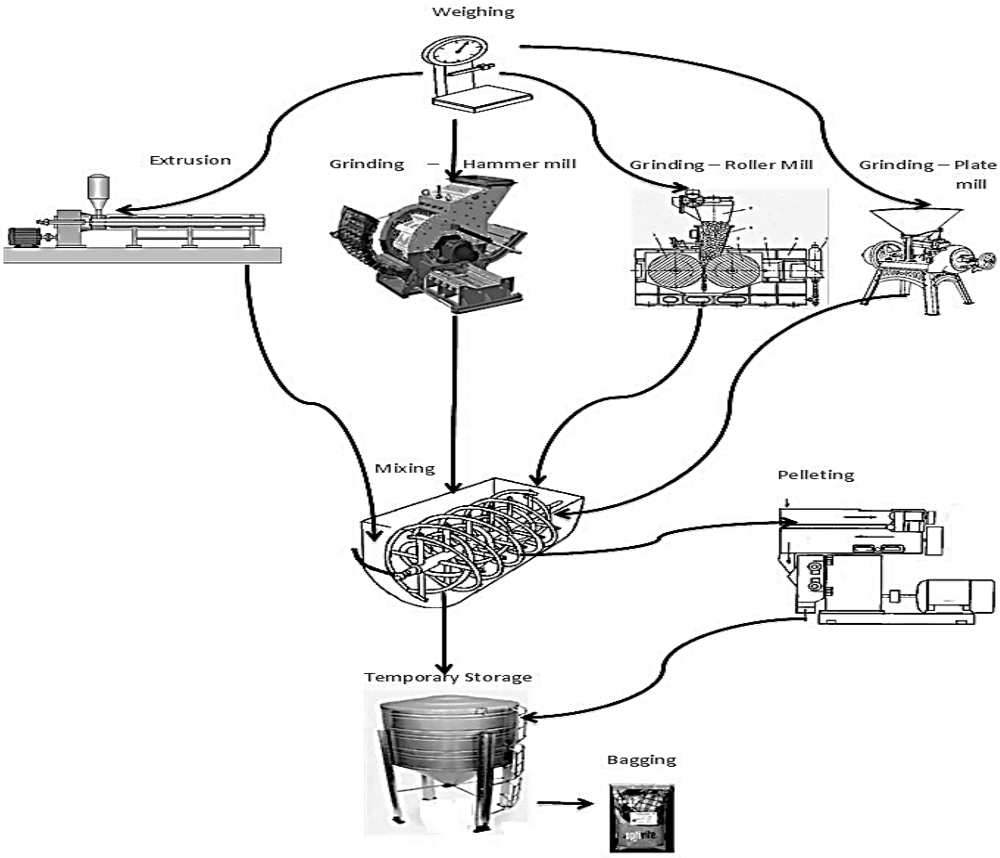

Figure 1 Basic unit operations in a feed mill

is associated with low capital output and capital labour ratios. Four levels of small scale feed milling were identified by the National Research Institute (1988) as follows:

i. 500 kg/d Shovel mixing
ii. 200 kg/h Cement mixer
iii. One t/ h Farm-scale mill and mix plant
iv. 2.5 t/h Small industrial-scale feed plant

The operations of these mills do not completely follow that of the large scale mills in terms of the equipment and process flow. The basic processes of these mills are grinding and mixing. These adjustments are basically due to low output; limited resources; relatively small target market; etc.

Glatz (2012) observed that the lack of regional small-scale feed manufacturing plants and high cost of imported feed are holding back the development of the small scale poultry sector in some Pacific Countries. According to Bourn et al. (1994), 85% of all the farm animal species in Nigeria were traditionally/locally managed. This high percentage of traditionally managed livestock is also responsible for the large number of small scale feed mills available and vice versa. Tewe and Mpoko (2001) reported that despite the 345% increase in the number of feed mills in Nigeria over an eight year period, there was 136% reduction in the efficiency of these mills.

According to Carbon Trust (2010), some key factors affect feed mills. Figure 2 illustrates some of these important key factors in this sector.

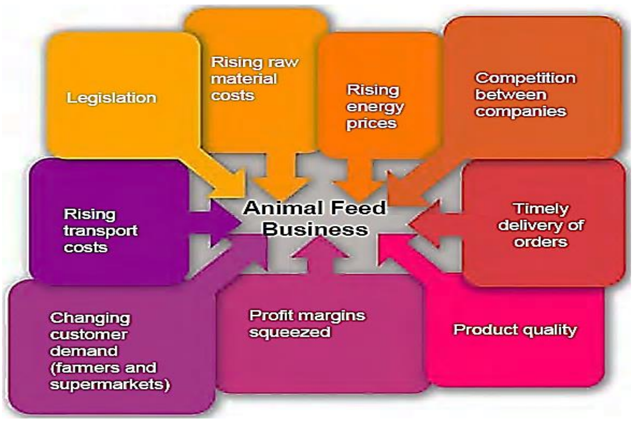

Figure 2 Key factors influencing the animal feed sector (Source: Carbon Trust, 2010)

Other factors include, the low quality of feed ingredients and poor technical expertise (Oladoja and Olusanya, 2009); high risk of accident – explosion, fire, structural failure; power failure, etc. (Van Fleet et al., 2013) and health problems (Mijinyawa et al., 2012). In other small scale mills, some of the inherent problems have been identified such as; health problems of mill operators (Omokhodion and Kolude, 2005); financial problems of small scale palm oil production (Adjei-Nsiah et al., 2012), etc.

This study is aimed at characterising small scale feed mills in a typical developing country thereby exposing their problems so as to compel and make room for further qualitative investigation and mitigation measures.

2 Methodology

2.1 Research design and characteristics of population

A survey design was adopted for this study in which 10 feed mills and 30 feed mill workers were randomly selected. The characteristics of each sample (individual feed mill) in the population investigated were; mill capacity, number of workers, mill operations and equipment used. Correlation between the feed mill capacity and the number of workers for the population was determined at 5% level of significance.

2.2 Method of data collection and analysis

In identifying and defining other characteristics, four major areas were investigated, which are:

A. **Power source**: The source of power for the milling operation was investigated to determine the power consumption and the cost.

B. **Unit operations and equipment:** The prevailing unit operations were investigated and studied to determine the miller's perception about the performance of each of the operation and their respective equipment.

C. **Energy utilization:** In estimating the energy available and consumed, the following empirical formulas reported by Abubakar and Umar (2006) were used:

1. Evaluation of Manual Energy Input: Manual energy input was estimated from Equation 1 and Equation 2;

$$E_{Mm} = 0.75\ T_a \quad (1)$$

$$E_{MF} = 0.68\ T_a. \quad (2)$$

Where: E_{Mm} is the male manual energy input (MJ) and *0.75* is the Energy input of an average adult male (MJ/h) (Norman, 1978). T_a represents the useful time spent by a male worker (h).

E_{MF} is the female manual energy input (MJ) and *0.68* is the Energy input of an average adult female (MJ/h). T_a represents the useful time spent by a female worker (h).

2. Liquid Fuel Energy: Liquid fuel energy was estimated using Equation 3 and Equation 4 below

$$E_{FLD} = 36.4D \quad (3)$$

$$E_{FLP} = 32P \quad (4)$$

Where: E_{FLD} represents the liquid fuel energy input for diesel (MJ) and D is the amount of diesel consumed (L). E_{FLP} is the liquid fuel energy input for petrol (MJ) and P is the amount of petrol consumed (L)

3. Electrical Energy (E_E): Data on electricity consumption (kWh) was estimated from the past bills collected over the year. These values were converted into common energy unit (MJ) by using appropriate coefficient (one-kilowatt-hour of electricity = 3.6 MJ) i.e. Equation 5

$$E_E = 3.6 \times kWh \quad (5)$$

4. Total Energy: Assuming negligible maintenance energy, the total energy was estimated from Equation 6 below.

$$E_T = E_M + E_{FL} + E_E \quad (6)$$

Where: E_M is the total manual energy (MJ); E_{FL} is the total fuel energy (MJ); E_E is the total electrical energy (MJ).

5. Energy Use Ratio (E_U): Energy use ratio required in the production of grower's mash and layer's mash were estimated from Equation 7 below:

$$E_U = \frac{E_{FP}}{E_T} \quad (7)$$

Where: E_{FP} is the total energy content of finished product (MJ) and E_T is the total energy input for operation (MJ).

E_{FP} was estimated from Equation 8 below:

$$E_{FP} = M_{FP} \times E_{CP} \quad (8)$$

Where: M_{FP} is the mass of finished product (kg) and E_{CP} is the energy content (Gross Energy) of a unit mass of product (MJ/kg).

The values of E_{CP} used are shown in Table 1.

Table1 Gross energy of some feed ingredients

Feed Ingredients	Gross Energy G.E, (MJ/kg)	Literature
Groundnut cake (GNC)	18.31	Udo and Umoren (2011)
SOYA	22.30	FAO (1987)
Wheat Offal	16.56	Udo and Umoren (2011)
Rice Bran	18.33	Udo and Umoren (2011)
Bone Meal	17.60	FAO (1987)
Limestone	18.55	Haaland and Tyrrell (1982)
Palm kernel cake (PKC)	19.27	Amaefule et al. (2009)
Maize	17.00	FAO (1987)
Brewery dried grain (BDG)	19.34	Amaefule et al. (2009)
Blood Meal	21.84	Udo and Umoren (2011)
Dried Fish	20.10	Udo and Umoren (2011)

D. **Workplace safety and hygiene:** The type of waste generated and their sources were investigated. A questionnaire was designed to elicit the discomfort experienced by the workers as a result of the dust generated during milling.

3 Results and discussion

3.1 Feed mill capacity

The average capacity of a small scale feed mill was found to be 2.87 t/d which according to the National Research Institute (1988) and Wesley (2005) can be classified under small industrial-scale feed plants. The capacity ranged from as low as 200 kg to a maximum of 10 t per day. About 55.6% of the feed mills investigated have capacities less than 1.5 t/d.

3.2 Feed mill workers

It was discovered that the feed mills have a maximum of ten male and six female workers with an average of six workers. Although 68% of these workers are male, it was discovered that those working at the production floor were predominantly men whose ages were between 25 and 40 years (60%) or between 15 and 25 years (40%) with an average work experience of one year. A worker in a feed mill works for straight 9 h (8:00am-5:00pm) without break. The only rest period these workers have is when production stops due to shortage in raw materials or power outage. The average load carried during work is usually above 20 kg.

Statistical analysis of the capacity and number of workers revealed a correlation ratio of 0.53 lower than a critical correlation ratio of 0.67 (at 5% level of significance) implying that there was no correlation between the number of workers and the feed mill capacity.

3.3 Power source

Two major sources were identified which are the national grid supply and diesel engine electric power generator. The maximum diesel consumption was 30 L/d but on the average, about 12.3 L of diesel was used per day which costs about ₦3000 (approximately $15). As regards the grid supply, 71.4% of the millers considered the billing system as too expensive. Around ₦40 000 (approximately $201) is being paid per month for a maximum of 120.19 kWh of electricity consumed per day.

3.4 Feed mill operations and equipment

Excluding material handling operations, the following operations were identified to be the basic unit operations in a small scale feed mill.

a) **Weighing**: Raw materials and finished products (feeds) were weighed using weighing scales. Table 2 shows that 28% of the respondents see this operation as the most stressful.

Table 2 Complaints of small scale feed millers

Complaints of Feed Millers	Percentage		
	Weighing	Grinding	Mixing/discharge
Most stressful operation	28	29	43
Most demanding (resources) operation	10	80	10
Timing	10	60	30
Most wasteful operation	11	78	11

b) **Grinding**: Grinding/milling of raw materials was done using home-made hammer mills (Figure 3) with beaters and screens of different sizes. This is considered as the most crucial and problematic operation because most of the respondents believed that it consumes most resources (especially energy), takes time and generates more waste. This is shown in Table 2.

Figure 3 Grinding operation using a hammer mill

c) **Mixing**: Products are blended together in a vertical mixer (Figure 4). In most cases, the output from the hammer mill is conveyed manually to the mixer. This is why 43% of the respondents believe that it is the most stressful operation as shown in Table 2. Some of the feed mills make use of shovel mixing (i.e. manually mixing feed ingredient on the floor with a shovel as shown in Figure 5) when there is power outage or when the mixer is faulty.

Figure 4 A vertical mixer

Figure 5 Shovel mixing

d) **Discharging/packaging**: The discharge and packaging of the feed was done directly under the mixer (Figure 6). There was no separate facility for discharging and packaging.

Figure 6 Discharging/packaging operation

3.5 Energy utilization

1. **Manual energy (E_M):** A maximum of ten male and six female workers who spend 8 h at work were found in the feed mills. This follows that from Equation 1 and Equation 2, the manual energy available for male and female workers are 60 MJ and 32.64 MJ respectively. This implies that the total manual energy available is;

$$E_M = \sum E_{Mm} + \sum E_{Mf} = 60 + 32.64 = 92.64 \text{ MJ}$$

2. **Liquid fuel energy (E_{FLD}):** The maximum amount of diesel consumed the feed mills was 30 L/d while petrol was not used; hence, from Equation 3,

$$E_{FLD} = 1092 \text{ MJ}$$

3. **Electrical energy (E_E):** For a given day, the maximum electric power consumed by a small scale feed mill was estimated as 120.19kWh; hence from Equation 5,

$$E_E = 3.6 \times 120.19 = 435.24 \text{ MJ}$$

Based on all these, the total amount of energy available in a small scale feed mill for the population under study is;

$$E_T = 92.64 + 1092 + 435.24 = 1619.88 \text{ MJ/d}$$

This maximum energy was used in producing a maximum of 10 t of feed per day; hence, the total energy used in producing 100 kg of feed is approximately 16.20 MJ.

Figure 7 shows clearly the energy sources in small scale feed mills in Ibadan.

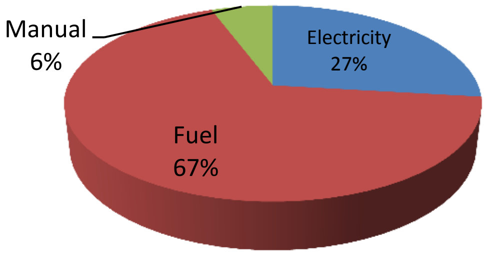

Figure 7 Energy consumption in small scale feed mills

The gross energy content of layer's and grower's mash are shown in Table 3 and Table 4 respectively while their energy use ratio is as shown in Table 5. The energy utilization of small scale feed mills is such that 162 kJ of energy is used in producing 1 kg of animal feed with energy content above 17 MJ.

Table 3 Gross energy content of layer's mash

Materials (Layers mash)	M_{FP} (kg)	E_{CP} (MJ/Kg)	$E_{FP} = M_{FP} \times E_{CP}$ (MJ)
GNC	5	18.31	91.55
SOYA	10	22.30	223.0
Wheat Offal	20	16.56	331.20
Rice Bran	10	18.33	183.30
Bone Meal	3	17.60	52.80
Limestone	2	18.55	37.10
Maize	50	17.00	850.00
			1768.95

Table 4 Gross energy content of grower's mash

Materials (Growers mash)	M_{FP} (kg)	E_{CP} (MJ/kg)	$E_{FP} = M_{FP} \times E_{CP}$ (MJ)
GNC	5	18.31	91.55
SOYA	5	22.30	111.50
PKC	30	19.27	578.10
Rice Bran	10	18.33	183.30
Bone Meal	3	17.60	52.80
Limestone	2	18.55	37.10
Maize	50	17.00	850.00
			1904.35

Table 5 Energy use ratio of finished feeds

	Layer's mash	Grower's mash
Total energy input (E_T), MJ	16.20	16.20
Total energy content of finished product (E_{FP}), MJ.	1768.95	1904.35
Energy Use Ratio (E_U) = E_{FP} / E_T	109.91	117.55

3.6 Workplace safety and hygiene

Dust is produced often by the grinding operation. Around 80% of the workers have suffered from some minor respiratory problems within the first few weeks of starting the job. Despite this large number, only about 13.33% make use of a form of protection from dust. In an attempt to reduce the dust, some of the feed mills visited ensured proper ventilation while 3.33% of these feed mills have a dust extractor.

The kind of waste generated from the feed mills include; metal scrap (e.g. worn-out beaters, screens and machine parts), spoilt raw materials, sacks, feed waste, etc. From Table 2, the grinding operation was identified to generate most waste. During the grinding operation, raw materials escape from the hopper of the hammer mill as a result of the impact of the rotating beaters. Also, some of the equipment are old and have leakages where materials escape from during the operation. Poor housekeeping was observed in the feed mills visited. It was discovered that the environment was dirty as shown in the Figure 8a and Figure 8b.

(a)

(b)

Figure 8 Poor house-keeping of feed mill environs

All the feed mills visited complained of high infestation from rodents and/or insects. Despite the fact that this is inevitable in a feed mill, the high infestation was a clear indication of poor housekeeping. To reduce this level of rodent infestation, some of the feed mills visited reared cats as a means of biological control (Figure 9). This method can create a problem of contamination of feeds and raw materials by the cats (Brian, 2010) and increased risk of cat scratch disease and other zoonotic bartonella infections (Chomel et al., 2004) by the workers and even customers.

Figure 9 Cats reared in a feed mill to control rodents

From the survey carried out, 70% of the workers complained of discomfort after work. This discomfort could lead to musculoskeletal disorders necessitating the need for assessing the risk of musculoskeletal disorder.

3.7 Solution to problems

In order to curb the problems, the following interventions are recommended;

1. **Engineering intervention**: In order to reduce or totally eradicate some of the problems in these small scale feed mills, agricultural engineers are required to;

a. Design a mill layout for proper operation

b. Design good and affordable equipment to reduce the level of the dependence on manual labour

c. Correct the problems associated with the locally made hammer mills

d. Ensure an ergonomically safe design and system

2. **Administrative intervention**: Some of the problems identified can be resolved by proper mill management and administration. Some of which are;

a. Good house keeping

b. Provision of PPE for workers

c. Good energy use

d. Providing necessary tools, equipment and machines that will reduce working stress

4 Conclusion

A preliminary investigation was carried out to characterise the small scale feed mills in a developing country. During the investigation, some imminent technical problems were discovered. The method of operation of these mills puts the environment and the workers who are predominantly young men in serious danger. The grinding operation was identified as the most critical operation in feed milling and it is responsible for the high energy consumption, relatively high amount of waste and dust generation. Based on the results gathered from the study, Table 5 shows the problems identified in the small scale feed mills alongside possible solutions. This paper reveals the problematic areas in small scale feed milling requiring further qualitative evaluation.

Table 5 Some problems facing small scale feed mills alongside suggested solutions

S/N	Problems	Effects	Causes	Solutions
1.	High cost of power	i. Low profit index ii. Dependence on manual operations like shovel mixing	i. Irregular power supply from grid ii. High cost of diesel iii. Equipment used are not energy efficient	i. Government intervention in public power supply ii. Making use of energy efficient equipment.
2.	High volume of waste	i. Rodent infestation ii. Low profit index	i. Poorly designed hammer mills ii. Leakages iii. Worn-out sacs	i. Providing a lid to cover hammer mill hopper where raw materials escape during grinding ii. Good maintenance which includes replacement of old and worn-out machines or machine parts. iii. Replacement of worn-out sacs.
3.	Dirty mill environs	i. Mill accidents e.g. slipping, falling, etc. ii. Contamination of feeds	i. Poor housekeeping	i. Regular cleaning ii. Feed spills should be cleaned up immediately iii. Proper feed mill layout to create more space
4.	Dusty environ	i. Respiratory disorders in workers ii. Poor visibility which could lead to accidents	i. Inefficient mill operations/equipment ii. Poor ventilation	i. Good ventilation should be incorporated in the design of feed mill buildings ii. Regular maintenance iii. Dust extraction iv. Making use of dust protection equipment.
5.	High rodents and insects infestation	i. Contamination of feeds ii. Destruction of properties.	i. Feed spillage during production ii. Poor housekeeping	i. Filling all the cracks, crevices and corners with element to prevent pests. ii. Used sacks should not be stored in the premises. They should be fumigated and sold. iii. Spraying the feed mill including roof and walls with insecticides iv. Cleaning all equipment and scraping all critical points where feed particles are accumulated.

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Nomenclature

E_{Mm}: Male manual energy input, MJ

E_{MF}: Female manual energy input, MJ

E_{FLD}: Liquid fuel energy input for diesel, MJ

E_{FLP}: Liquid fuel energy input for petrol, MJ

E_{M}: Total manual energy, MJ

E_{FL}: Total fuel energy, MJ

E_{E}: Total electrical energy, MJ

E_{T}: Total energy input for operation, MJ

E_{FP}: Total energy content of finished product, MJ

E_{CP}: Energy content (gross energy) of a unit mass of product, MJ/kg

M_{FP}: Mass of finished product, kg

D: Amount of diesel consumed, litres

P: Amount of petrol consumed, litres

T_{a}: Useful time spent by a worker, hours