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Establishment and Testing of Indigenous Small Scale Moringa Leaves Powder Processing Plant in Nigeria

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ABSTRACT
A small scale dry moringa leaves powder processing plant of 300 kg per day capacity was established in Federal Polytechnic Bida, Niger State of Nigeria. All the machine parts were fabricated in the Institution. The plant is made up of the following sections; leaves washing unit, draining unit, drying and the milling units. All machine parts that will get in direct contact with the moringa leaves were made of stainless steel. The results of testing shows that all the proximate composition of the samples significantly ($p<0.05$) changed with increased in drying temperatures. The moisture content, crude protein and fat content of the dried leaves sample decreased with increase in drying temperature from 34°C to 49°C. While carbohydrate, fibre and ash content increased significantly ($p<0.05$) with increased in drying temperature of the moringa leaves samples. The milling efficiency of the hammer mill ranged between 60.39 % and 96.83 %. The highest milling efficiency of 96.83 was obtained from interaction between 18 numbers of hammer head assembly, moringa moisture content of 9 % and speed of 1460 r.p.m. The milling efficiency increased with increase in speed of milling and increase in number of hammer head but decreased with increase in moisture content of the leaves. In conclusion dried moringa leaves contained more fat, fibre, protein and carbohydrate than the fresh leaves.

Keywords: *Provide between four to six keywords arranged in alphabetical order.*

1 INTRODUCTION

Moringa leaves powder is a product obtained as result of milling dry moringa leaf. The leaves of the *Moringa oleifera* tree are very nutritious. They can be consumed freshed, cooked or dried. The dried moringa leaves retain their nutrient content and it is easily converted into leaf powder (Satya *et al.*, 2012). Moringa leaf powder is used as food supplement and can be consumed in different ways. A teaspoon of the leaf powder can be mixed with juices or beverages. One teaspoon of moringa can provide a full range of nutrients required by the body. Moringa leaf powder can also be mixed with vegetables or soup that is prepared for consumption. According to Diatta, (2001), 25 g of moringa powder can be administered to pregnant women daily to improve their prenatal nutrition. Apart from plain leaf powder, moringa powder is also made in capsules. According to Marcu (2005), no negative effects from daily consumption of moringa leaves and seeds have ever been reported and further indicated that moringa has the following health benefits: reduces cholesterol levels and triglycerides ("bad" fats), controls blood sugar and helps normal sugar and energy balance, offers vitamins and minerals vital for maintaining normal physiology and offers powerful anti-aging and anti-inflammatory natural substances, many with anti-cancer properties. The leaves are good source of vitamins A, B, and C and minerals, particularly iron and sulphur containing amino acids.

Fuglie (1999) and Fuglie (2000) reported that moringa leaves processing have socio-economic and numerous health benefits which include; it serve as sources of income to its producers and dealers. Moringa leaves contain more Vitamin A than carrots, more calcium than milk, more iron than spinach, more Vitamin C than oranges, and more potassium than bananas.

It was observed that the current processing methods of moringa leaves powder is physically demanding and lacks in quality and efficiency. Without standard steps to follow or procedure that will produce hygienic and, quality moringa leaves powder. Most of the moringa leaves powders produced are counterfeit and adulterated product due to poor sanity quality of the processing methods (Fuglie 2000; Chris 2010). Chris (2010) reported some of the problems faced by moringa dealers to include poor quality of products. The attitude of buyers towards the locally processed food supplements in general is poor, it is being regarded as inferior products compared to imported alternatives. The locally processed product is perceived to be of poor quality due to adulteration during processing.

The general production process and packaging of moringa powder is simple that it could be done in every home with a moringa tree. The products are poorly labelled or branded. While initially there was high demand for the powder, the influxes of many fake products (with similar colour and taste) were put on the market as moringa powder undermined the demand. Some dealers had abandoned moringa powder production for other moringa products with more specialised/ processing and packaging techniques. According to Chris (2010), about 82% of its dealers and consumers complained about poor processing methods, lack of standard production methods and quality control system. The texture of the product differs between different processors. Hence, the design, fabrication and testing of moringa leaf powder processing plant capable of processing acceptable, hygienic and good quality moringa leaf powder is of immense significance in alleviating some of the shortcoming associated with moringa leaf powder production.

The aim of the project was to establish a 300 kg per day moringa leaves powder processing plant that is capable of producing hygienic and good quality moringa leaf powder, to also provide source of avenue for local processor to process their product. In addition the processing plant can be used as teaching aid, provide rural employment for the unemployed youths and generally contribute to rural development in the state.

2 METHODOLOGY

2.1 Processing Centre Layout

The Moringa leaves powder processing plant layout at the Federal Polytechnic Bida has the following four main sections as shown in Figure. 1.

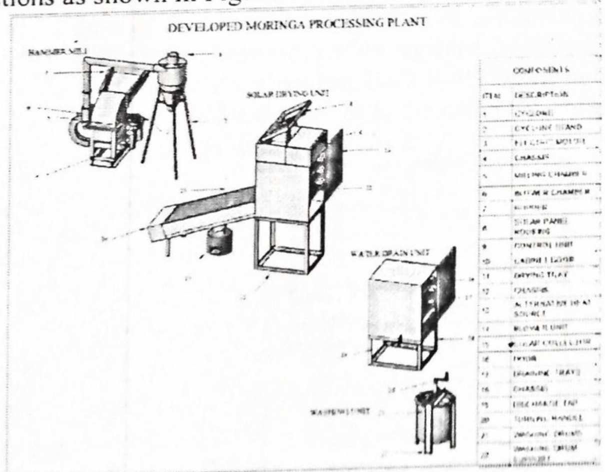

Figure 1: Processing plant layout

1. Washing and cleaning areas: This is the area where the striped leaflets were collected, cleaned to discard diseased and damaged leaves before weighing.
2. Draining chamber: Draining of excess water from the leaves was carried out by spreading the leaves on perforated trays made with stainless steel inside the draining chamber. The drained water was collected at the water collector and channel out through a hose and valve fixed inside the chamber
3. Drying Section: This is the section where the drying of the drained leaves takes place. The drying process is achieved using direct solar heating or heat generated from burning of biomass.
4. Milling Section: This is a hammer mill powered by a 15 Hp electric motor. The milling of the dried leaves to powdery form takes place here.

2.2 PRODUCTION PROCESS

The production process of the small scale moringa leaves powder processing plant at Federal Polytechnic Bida is explained in Fig. 2. The leaflets were striped from the leaf petiole and diseased and damaged leaves were discarded. The leaflet were washed using the developed washer with clean potable water to remove dirt; the leaves washed again in 1% saline solution (NaCl) for 5 minutes to remove microbes Satya, *et al.* (2012). The leaves were further washed with 70% ethanol which was followed by twice washing with distilled water. Draining of excess water from the leaves was carried out by spreading the leaves on perforated trays made with stainless steel inside the draining chamber. The leaves were dried to the maximum recommended moisture content of 10% using the automated solar dryer. The dried leaves were milled and sieved using the developed stainless steel hammer mill. The moringa leaf powder was finally dry to moisture content below 7.5% Satya, *et al.* (2012).

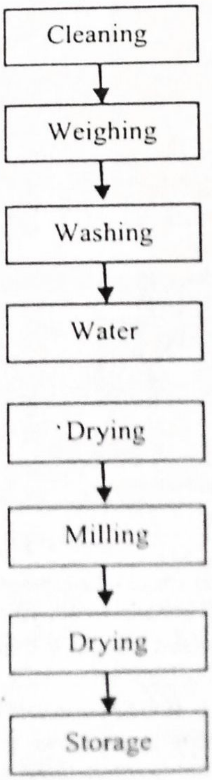

Fig. 2: Processing process of the small scale moringa leaves powder processing plant at Federal Polytechnic Bida

2.3 THE PLANT'S COMPONENTS AND PERFORMANCE ASSESSMENT

The following machines and equipment were installed in the Agricultural and Bioenvironmental Engineering Department of Federal Polytechnic Bida.

2.3.1 Washing Chamber

This unit is made of stainless steel plate (2mm) and 2 mm stainless pipe which serves as the stirrer. It is cylindrical in shape with two cylinders, the inner cylinder is perforated with diameter of 0.5 m, while the external cylinder has diameter of 0.6 m. The heights of the two cylinders are 0.9 m each. The washing drum is shown in Plate 1.

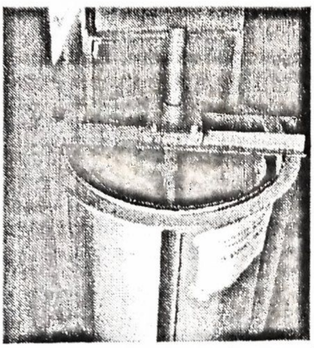

Plate 1: Moringa Leaves Washing Equipment

2.3.2 Draining Chamber

This unit is made of stainless steel materials. It is made up of four trays with dimensions 0.9 m x 0.9 m x 0.8m each. Two of the trays (trays number 1 and 3) are perforated for draining of water while the other two (trays number 2 and 4) are not perforated and serves as the water collectors. These trays were inclined for easy discharge of water out of the chamber. Each of the water collector trays has a nozzle for discharge of the collected water out of the chamber. It is shown in Plate 2

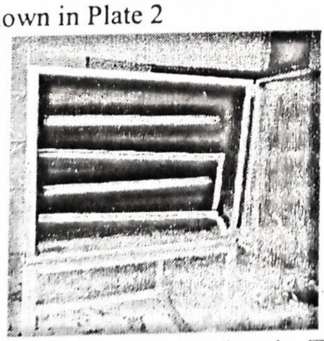

Plate II: Draining Chamber showing the Trays and water collectors

2.3.3 Drying Chamber

Drying chamber is made of stainless steel plate (1mm) and galvanize sheet (1mm) with glass fibre as an isolating materials between them. The chamber is made up of 0.9m x 0.9 x 0.8m dimension it contains an exhaust outlet portion at the upper part of the door. It is joined with an adjustable solar collector attached with the biomass heating unit (Plate IV) at the bottom. The drying chamber has an opening of 0.05 m through which pre-heated coming from solar collector passes into the drying chamber. The drying trays were made with stainless steel mash and space was provided round the trays in order to allow free air circulation within the chamber. The essence of providing this free space is to provide equal drying facility to the entire moringa product inside the drying chamber and thus increase the rate of drying. A two exhaust fans were fixed at the bottom of the drying chamber and covered at the end with filtering screen. The drying chamber is shown in Plate III. A temperature sensor capable of sensing temperature difference between 0° and 100° was fixed inside the chamber. A control system that received signal from the sensor and active and deactivate the exhaust fan was also fixed on the top of the chamber. The control system is shown in Plate IV

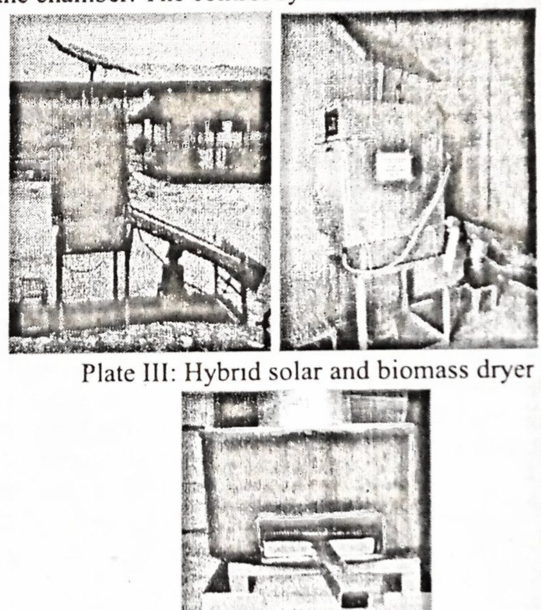

Plate III: Hybrid solar and biomass dryer

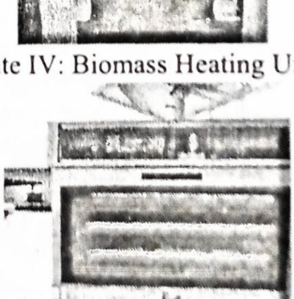

Plate IV: Biomass Heating Unit

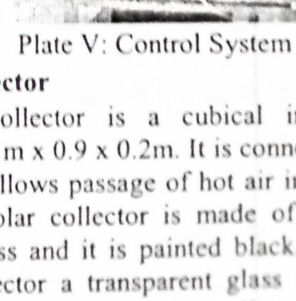

Plate V: Control System

2.3.4 Solar Collector

The solar collector is a cubical in shape with dimension of 1.6 m x 0.9 x 0.2m. It is connected to drying chamber and it allows passage of hot air in to the drying chamber. The solar collector is made of mild steel of 0.002 m thickness and it is painted black. At the upper part of the collector a transparent glass sheet (0.005 thick) was fixed 0.05 m above the collector. The bottom and sides portion of the collector were fitted with non-corrosive galvanize iron sheets and between them a glass fibre of 0.05m thickness was fixed. At the bottom of the collector a space of 0.05 m was provided between it and the internal galvanize sheet. This is to allow free circulation of heat generated from burning of the biomass. The solar collector was designed to be adjustable of between the angles of 10° to 40° based on latitude of Nigeria which is between the ranges of 4° to 14° in order to allow utilization of the solar system anywhere in Nigeria. It was embedded with adjustable legs in front as shown in Plate III.

2.3.5 Solar Panel

The solar panel used is 72 watt solar panel and it is shown in Plate 3. A marine deep cycle battery that has the advantage of discharging and recharging ability was used. The battery serves as power accumulator in a case where by the solar drying will take place over night in this case it need to work for almost 18 hours without charging, this call for selection of a large size battery of 18 amp capacity.

2.3.6 Hammer Mill

The hammer mill is also made up stainless steel materials. It has 21 numbers of rectangular beaters and eight numbers of circular beaters. The rectangular beaters are 0.11m x 0.05 x 0.006 m in dimensions while the circular beaters have diameters and thickness of 0.22m x 0.006m respectively. The milling chamber has concave sieve at the bottom. Attached to base of the machine is extractor fan that extract the moringa leaves powder and conveyed them out of the machine via the delivery funnel. The machine is power by 15 hp electric motor with speed of 1460 rpm. The machine is shown in Plate 4.

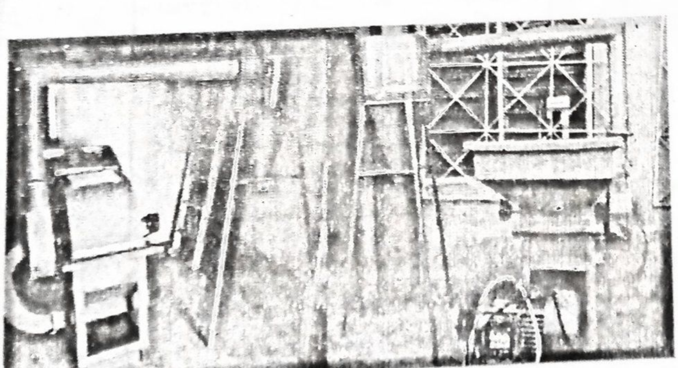

Plate 4: Hammer Mill

The following procedures were followed to determine the machine performance parameters and moringa leaves powder quality.

The green house effects were adopted as the main working principles of this hybrid solar dryer. The sources of heat for the dryers are indirect solar energy and heat generated from heating of Biomass materials. The heat energy from any of the two sources (depend on the one in usage) heat up the fresh air entering from atmosphere through air inlet and is passed through the bottom of the drying chamber and it collects the moisture from moringa leaves and it is exhausted through air outlet. As the air passed into the drying chamber it temperature increases, as the temperature reaches preset 49^{0}c the temperature sensor inside the drying chamber send a signal to the control system which in turns activated the hot air extractor fan situated at the bottom of the drying chamber. The fan blows in filtered air into the chamber which cools the temperature of the chamber. As the temperature decrease to 20^{0}c the temperature sensor reactivated again and sends a signal to the control system which in turns deactivated the extractor fan. This process continues automatically. The dried moringa leaves were then fed into the hammer mill which ground them into powder form as shown in Plate VI below.

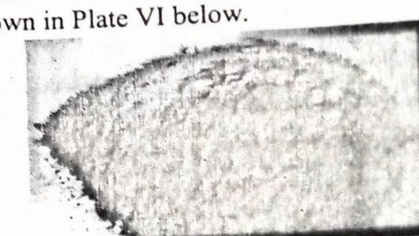

Plate VI: Milled Moringa Powder

2.4 TESTING OF THE PLANT

Two different experiments were conducted to test the performance of the mini plant. In the first experiment the performance of the drying section was tested while in the second experiment the performance of the milling section was tested.

2.4.1 Testing of the drying unit

In this experiment the moringa leave samples were dried to 10.5 % moisture content at four different temperature of 34°C, 39°C, 44°C and 49°C using the developed equipment. In each experiment the proximate composition of the dried sample was determined. Each of the experiment was replicated three times and the average value were determined as presented in Figure 2

Determination of Moringa leaves powder Quality

The quality of the moringa leaves powder was determined by evaluating its proximate composition. The analysis carried is as follows:

Proximate Composition

The Proximate composition including moisture, fat, crude protein, ash, and carbohydrate contents of beverage samples was evaluated at the National Cereal Research Institute Badeggi, Bida, Niger State, according to AOAC (2000) and AOAC (2005)

2.4.2 Testing of the milling unit

Experimental setup and procedure for developing the design matrix

In this experiment five levels-three factors (5^3) central composite rotational design (CCRD) of response surface method (RSM) was used. The factors and their levels are; hammer head of 21- heads, 18- heads, 14- heads, 10-

heads and 7- heads assembly, milling speed of 1582 rpm, 1460 rpm, 1360 r.p.m, 1260 rpm and 1192 rpm, moringa leaves moisture content of 7.9 %, 9 %, 10.5 % 12 % and 13% in order to investigate the milling efficiency of the machine. The experiment consist of 20 experimental runs ($2^k + 2k + m$, where k represent the number of factors independent variables)), involving eight factorial points (2^3), six axial point (2 x 3), and six replicated centre points at zero level (Gbabo 2016 ; Aworanti *et al.*, 2013).

Determination of machine milling efficiency

This is the measure of the degree by which the grains are reduced in size and was determined as reported by Nwagwe *et al.* (2012) and Nasir (2005)

$$M_E = \frac{M_O}{M_I} \times 100 \qquad (1)$$

where, M_E = the milling efficiency (%)

M_O = the amount of the material passing through the sieve (kg)

M_I = the total weight of the material feed into the machine (kg)

3 RESULTS AND DISCUSSION

Effects of variation of drying temperature on proximate composition of the moringa leaves

The proximate composition of the sample was determined and the result showed that the fresh moringa leaves had moisture content 80.22g/100g, fat content 1.03g/100g, protein content of 9.95g/100g, fibre content of 2.9g/100g, ash and carbohydrate contents of 1.59 and 4.31g/100g respectively. All the samples were dried to almost 10.5% moisture content. The sample dried using indirect solar energy at 34°C had fat content 2.62g/100g, protein content of 30.08g/100g, fibre content of 16.38g/100g, ash and carbohydrate contents of 4.48 and 35.94g/100g respectively. While that dried using the furnace at 49°C had fat content 2.43g/100g, protein content of 21.2g/100g, fibre content of 17.6g/100g, ash and carbohydrate contents of 4.68 and 43.3g/100g respectively as shown in Figure 3.

From Figure 3 all the parameters significantly ($p<0.05$) changed with change in drying temperatures. Crude protein of the samples decreased significantly ($p<0.05$) with increased in drying temperature. Samples dried at 34°C had value of 30.08 g/100 g, at 39°C had value of 27.28 g/100 g, 44°C had value of 25.22 g/100 g and at 49°C had value of 21.2 g/100 g. Similar trends were observed for fat content which had values of 1.03 g/100g for fresh leaves, 2.62 g/100 g at 34°C, 2.6 g/100 g at 39°C, 2.54 g/100 g at 44°C and 2.43 g/100 g at 49°C. The decrease in protein and fat content with corresponding increase in dying temperature could be as result of denaturalization. This result is similar to that reported by Alakali *et al.* (2015)

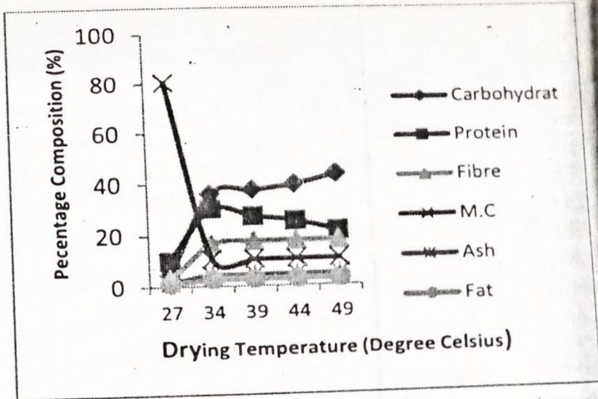

Figure 3: Effect of variation in drying temperature on proximate composition

The carbohydrate, fibre and ash content increase[d] significantly ($p<0.05$) with increased in dryin[g] temperature of the moringa leaves samples. Samples drie[d] at 34°C had lower carbohydrate content of 35.94g/100 g fibre content of 16.38g/100 g and ash content of 4.4[8] g/100 g, the values increased significantly to 43.3, 17[.6] and 4.68 g/100 g respectively when the leaves were dri[ed] at 49°C. This is in agreement with the values reported [by] Alakali, *et al* (2015), Gernah and Sengev (2011). Kum[ar] *et al.* (2014) and Alakali, *et al* (2015), reported that mi[ld] drying conditions with lower temperature may impro[ve] the product quality but decrease the drying rate.

The result shows that dry leaves are better source [of] fat, fibre, protein and carbohydrate than the fresh lea[ves]. The trend in change in the proximate composition of [the] *M. oleifera* leaves at different drying conditions agr[ees] with the work of Alakali, *et al* (2015) and Adeyemi *e[t al.]* (2014).

Effects of machine parameters on milling efficien[cy of] the hammer mill

The machine parameters investigated in this s[tudy] include: number of hammer head, speed of milling, moisture content of the moringa leaves and the respo[nse] the milling efficiency. The result of their interactio[n is] presented in Table 1.

Table 1: Effects of interaction between hammer head, moisture content and speed on machine milling efficiency

Std order	Run order	No of Hammer Beaters	Speed of rotation	Moisture content (%)	Milling Eff.
11	1	14	1192	10.5	71.48
19	2	14	1360	10.5	73.18
15	3	14	1360	10.5	73.2
9	4	7	1360	10.5	63.2
6	5	18	1260	12	71.87
20	6	14	1360	10.5	73.2
12	7	14	1528	10.5	79.5
3	8	10	1460	9	72.58
1	9	10	1260	9	67.4
2	10	18	1260	9	85.33
13	11	14	1360	8	79.32
17	12	14	1360	10.5	73.21
18	13	14	1360	10.5	80.19
4	14	18	1460	9	96.83
14	15	14	1360	13	60.39
5	16	10	1260	12	64.18
16	17	14	1360	10.5	73.25
10	18	21	1360	10.5	89.92
7	19	10	1460	12	62.4
8	20	18	1460	12	76.14

Milling Efficiency

From Table 1 the milling efficiency ranged between 60.39 % and 96.83 %. The highest milling efficiency of 96.83 was obtained from interaction between 18 numbers of hammer head assembly, moringa moisture content of 9 % and speed of 1460 r.p.m, while the least efficiency of blending of 60.39 % was obtained from interaction between 14 numbers of hammer head assembly, moringa moisture content of 13 % and speed of 1360 r.p.m.

Relationship between speed of milling and hammer head

The response surface for milling efficiency based on relationship between speed of milling and type of hammer head is presented in Figures 4. The milling efficiency increased from 69.75 % to 88.4 % as the speed of milling increased from speed of 1260 r.p.m to 1460 r.p.m. This could be due to increase in impact force, cutting and shearing actions of the hammer heads with increased in rotational speed. Jayesh (2009) had reported that rotational speed was found to be a significant factor to size reduction of solid materials. Where lower speed of blending resulted to low blending efficiency, while higher speed of blending resulted to higher blending efficiency. Also it was obvious that the milling efficiency increase from 69 % to 88 % with increased in number of hammer heads from 10 o 18 numbers.

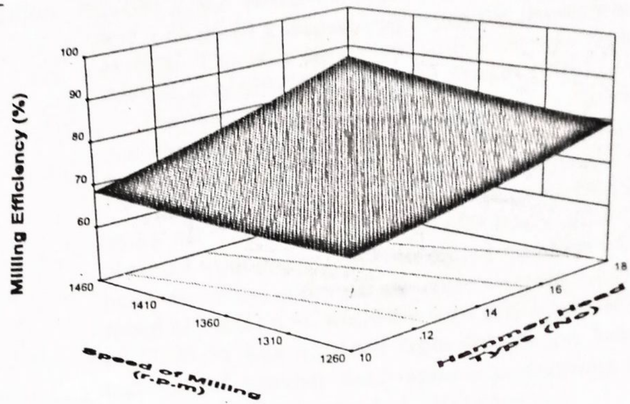

Figure 4: Response surface for milling efficiency with respect to speed and hammer head

Relationship between moisture content and speed of milling

The response surface for milling efficiency based on relationship between moisture content and speed of milling is presented in Figures 5. The milling efficiency decreased from 78 % to 68 % as the moringa leaves moisture content increase from 9 % to 12 %. This could be as result of increase in friction and resistance to segregation of the leaves as the moisture content increased. The milling efficiency was also observed to increase from 76 % to 84 % as the speed increased from 1260 r.p.m to 1460 r.p.m. This could be as result of more segregation of the materials with increase in speed of milling

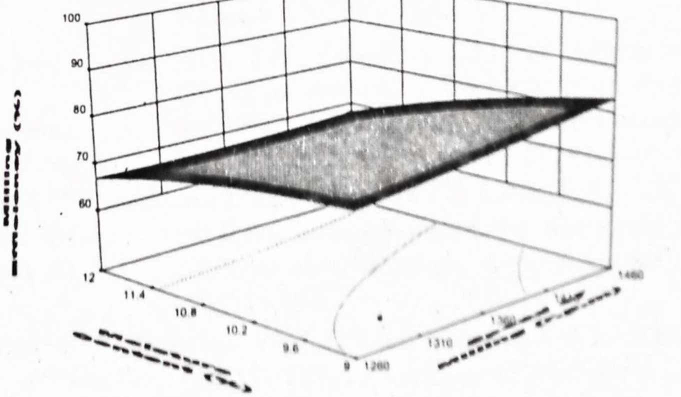

Figure 5: Response surface for milling efficiency with respect to moisture content and speed

Relationship between speed of moisture content and hammer head

The response surface for milling efficiency based on relationship between moisture content and hammer head are presented in Figures 6. The milling efficiency was observed to decrease from 75.5 % to 63 % with increase in moisture content from 9 % to 12 %. This could be as result of increase in resistance of the leaves to segregation due its high water content.

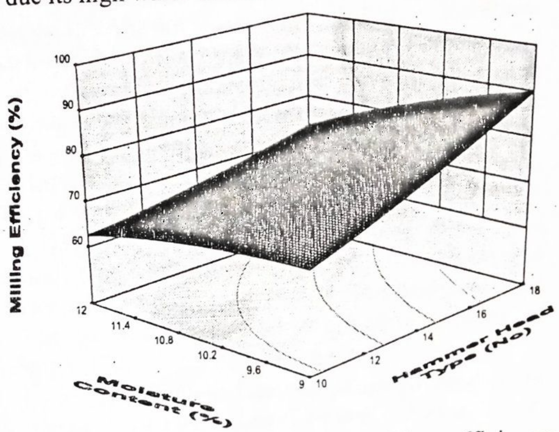

Figure 6: Response surface for milling efficiency with respect to moisture content and number of hammer head

The milling efficiency was also observed to increase from 75.5 % to 90 % with increase in number of hammer heads from 10 to 18. This was as result of more contact between the leaves and the hammer head with increase in number of the heads. This conforms to the result of an earlier study by Rachel *et al.* (2007) were blade design affect segregation of materials.

Optimisation of the machine parameters was carried out using numeric technique in rsm with goal of maximising the milling efficiency. It gave the optimum values of 18 number of hammer head, moisture content of 9% and speed of 1460 r.p.m., while the milling efficiency and desirability are 96.34 % and 0.988 respectively.

4 CONCLUSION

The Federal Polytechnic Moringa Leave Processing Plant is the first complete indegeneous Processing Plant that has been established in the Polytechnic sponsored by TETFUND after elaborate research work on the development of all components of the plant. Results on performance test

The results shows that all the proximate composition of the samples significantly ($p<0.05$) changed with increased in temperatures. The moisture content of the leaves decreased with increase in drying temperature from 34°C to 49°C.

Crude protein and fat content of the dried leaves sample decreased from 30.8g/100 g and 2.62g/100 g respectively, to 21.2g/100 g and 2.43g/100 g respectively with increased in drying temperature.

The carbohydrate, fibre and ash content increased significantly ($p<0.05$) with increased in drying temperature of the moringa leaves samples. Samples dried at 34°C had lower carbohydrate content of 35.94g/100 g, fibre content of 16.38g/100 g and ash content of 4.48 g/100 g, the values increased significantly to 43.3, 17.6 and 4.68 g/100 g respectively when the leaves were dried at 49°C. This is in agreement with what was reported by Alakali, *et al* (2015), Gernah and Sengev (2011).

The result shows that dry leaves have more concentration of fat, fibre, protein and carbohydrate than the fresh leaves.

The milling efficiency ranged between 60.39 % and 96.83 %. The highest milling efficiency of 96.83 was obtained from interaction between 18 numbers of hammer head assembly, moringa moisture content of 9 % and speed of 1460 r.p.m, while the least efficiency of blending of 60.39 % was obtained from interaction between 14 numbers of hammer head assembly, moringa moisture content of 13 % and speed of 1360 r.p.m.

The milling efficiency increased with increase in speed of milling and increase in number of hammer head but decreased with increase in moisture content of the leaves.

The results of the optimisation of the machine parameters gave the optimum values of 18 number of hammer head, moisture content of 9% and speed of 1460 r.p.m., while milling efficiency and desirability are 96.34 % and 0.988 respectively.

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