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Optimisation of Cassava Pellet Processing Method

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Abstract

Processing cassava onto pellets, an internationally acceptable and commercially rewarding cassava product minimizes quantitative and qualitative losses. Pellet samples were produced through the conventional chipping, drying, milling then pelleting with and without steaming (CDMP-S and CDMP) and modified process of grating, dewatering then pelleting and steaming (GDWP-S). Investigations for storageability, durability, uniformity in dimension and nutritional qualities resulted in pellets with moisture content of 9%, uniformly light brown in colour, free from objectionable odour with no sign of deterioration after 90 days of storage. The durability index and fine formations are 99.8% and 0.2%, 98.8% and 1.2%, 99.4% and 0.6% for CDMP-S, CDMP and GDWP-S respectively. The average lengths of 2.81, 2.23 and 2.74 cm and diameters 0.76, 0.73 and 0.67 cm respectively fall within the standard. The carbohydrate contents are 82.9%, 83.4% and 84.5% and cyanogenic glycosides contents of 14.18mg/100g, 14.32mg/100g and 10.13mg/100g respectively. The pellets produced from the modified process GDWP-S in addition to satisfying the standard colour code also conforms favourably well in terms of strength, durability and nutritional quality with the conventional CDMP-S and are better than the cold pellets from the conventional process CDMP. These are in addition to the reduction of about eight hours of chip drying operation in the modified process. This reduction in time and energy with associated quality products show that the modified process is a promising approach in the production of pellets acceptable in the export market.

KEYWORDS: cassava, pellet, optimisation, processing, grating

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INTRODUCTION

Cassava is a very important food crop with high nutrient content, which makes it a major source of dietary calorie (about 25 - 56%) especially for people in southern Nigeria (Igbeka, 1980) and other cassava producing regions of the world. FAO (1997) reported that over the period of 1982 - 1995 the use of cassava for direct human consumption in its fresh or processed form has declined. This decline has been most significant in Asia and to a lesser extent in Africa. Recently it has taken the status of a cash crop in Nigeria because of its ability to serve as important and cheaper source of raw materials in industries especially in the animal feed industry. There is therefore the need to develop the product to make it an effective means of promoting economic empowerment and social development, especially in developing countries like Nigeria.

Cassava roots are highly perishable with a post harvest life of less than 72 hours but they can be stored underground for longer periods if they are not detached from the plant (Lincoln and John, 2005). Once harvested, they undergo rapid physiological changes resulting in quality deterioration if left unprocessed within 24 - 48 hours (Oyewole and Asagbara, 2003; Ashaye *et al*, 2005). This may be accelerated in root with mechanical damage during harvesting, transportation and handling. Loss of between 20 - 30% has been observed for fresh cassava due to inadequate quality storage facilities (Kumar *et al*, 1996). Hence it is appropriate to preserve the product and make it available all year round. One way of postharvest preservation is by processing to a number of dry food and exportable products which store longer (Hahn and Keyer, 1985). This minimizes quantitative and qualitative losses, ensures steady production and availability of other products.

One of the greatest advantages that cassava has over other tropical starchy root crops is that the roots can be put to many uses (Onyekwere *et al*, 1994). Almost all the cassava produced in Nigeria is used for human consumption with less than 5% being used in industry (Taiwo, 2006). These food products include *gari* (fried cassava granules), *fufu* (cassava dough), *lafun* (fermented cassava flour), tapioca (cassava flakes), starch etc. The leaves are also eaten as green vegetable being a rich and cheap source of protein and vitamins A and B (Hatmann, 2003; Lincoln and John, 2005).

In Nigeria, cassava is increasingly gaining ground as a popular cash crop with a large proportion planted purposely for sale to local industries and export (Table 1). Planting of high yielding varieties introduced by the International institute for Tropical Agriculture (IITA) with good agronomic practices has resulted in higher cash income. Cassava chips and pellets are the two exportable products that are widely becoming popular in Nigeria. The chips, the most common form in which dried cassava roots are processed and marketed in most exporting countries, are dried irregular slices of the roots that vary in sizes but not exceeding 5cm in length.

Table 1: Annual Demand for Cassava Products in Nigeria.

Products	**National Demand (Tonnes)**	**Export Demand (Tonnes)**
Cassava based feed.	7,811,000	NA
Gari, fufu and others	1,876,000	NA
Cassava chips	91,243,245	NA
Cassava pellets	NA	18,900,000
Starch	444,250	800,000
Ethanol (Litres)	114,000,000	270,000,000

Source: FMST, 2003

Chips are packed in sacks of cotton, multicraft paper bags or clean jute bags. They are produced extensively in Thailand, Malaysia, Indonesia and some African countries. The major problems associated with cassava chips include: mould formations in long distance shipment because of heating and sweating by hot weather condition during the day and moisture absorption from the cold high humidity sea breeze. Chips occupy more space during packaging and transportation thereby results in higher cost of handling. Also because of their thin slices and fragile nature, they get broken down into smaller fractions during transportation and handling operations thus failing the international standard required for cassava chips.

The need to improve the uniformity in the shape and size of cassava chips required by the users stimulated the production of pellets which becomes the most important form into which cassava could be processed for export. Pellets are dried and hardened cylindrical particulate materials about 2-3cm long, 0.4-0.8cm in diameter and uniform in appearance and texture (Olm-Olyne, 2004) having about 9% moisture content wet basis which makes for good storability (Onyekwere *et al*., 1994).

Processing of cassava pellets can be done in two ways. It can be done by the use of the roots and leaves in the ratio 4:1 to make composite pellets. The most commonly used and acceptable method involves the conversion of peeled cassava roots into pellets (see flow chart in Fig. 1). The process involves feeding dried and milled flour into a pelleting machine which presses the chips/mash before extrusion through a large die. The heat and moisture in the chips help in the formation of pellet-like shaped product known as soft pellet. Later process development involves milling of chips followed by steam extrusion through a large die to obtain partially gelatinized pellets that become hardened on cooling known as hard pellets. They have been observed to have a longer shelf life when dried to 8% moisture wet basis.

The production of pellets has recently been increasing as they meet a ready demand in the European market. In the production of pellets there are many national and regional variations in the processing method, degree of mechanization and the quality of the finished product (Fish and Trim, 1993). Roots may be washed and peeled before chipping as practiced in Indonesia or chipped directly after harvest without peeling though may be debarked if meant for animal feed as is more common in India, Thailand and Malaysia (Bruinsma *et al*,, 1983; Balagopalan *et al*, 1988).

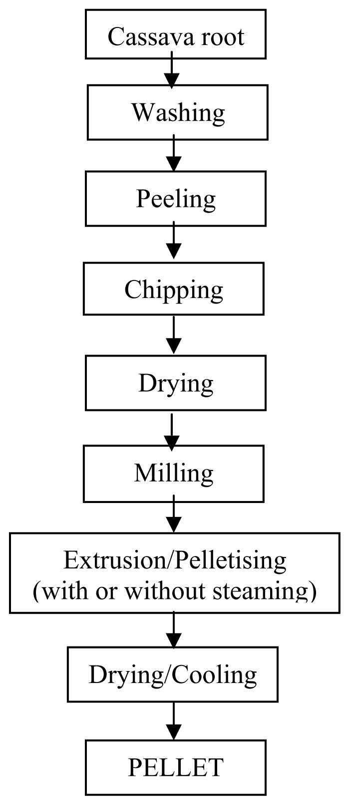

Fig. 1: Flowchart for pellet production.

Some of the advantages derived from processing cassava roots into pellet making them suitable for export include: uniformity in quality, strength (from partial gelatinization of starch and subsequent binding of the gelled starch) (Rajamma *et al,* 1994), light weight, less storage volume as well as retention of quality during shipment.

From the above it is important to note that acceptability of the product in the international market is an important factor that requires extensive study on the handling, processing, cost and time of production. It is therefore desirable to develop cost effective and time saving methods in order to increase output and produce a value-added product. This agro-industrial development venture will not only provide employment opportunities but also reduce the poverty level in the country.

This study therefore aimed at investigating the processing methods and reducing the number of unit operations as well as processing time involved in the production of cassava pellet with a view to delivering good quality products obtainable at the lowest production cost as well as the shortest production time.

MATERIALS AND METHOD

The study was carried out at the Cassava Utilization Unit of the International Institute for Tropical Agriculture, Ibadan, Nigeria. Fresh Cassava Roots (TMX 4763, about eighteen months old on the field) were harvested from IITA farm, washed with clean water and allowed to drain. The roots were then converted to chips or grated to pulp using an IITA designed combined chipping, slicing and grating machine powered by a 5HP electric motor. Drying operations were done using a forced-air cabinet dryer (Niji Lucas Ltd, Lagos). Hot air re-circulates in the dryer after passing through a condenser which absorbs moisture to reduce the energy utilized in heating rehydration. Samples were milled in an IITA designed milling machine operated by a 7.5 HP electric motor (Type Y132S_2-2, Viking Exclusive) with a speed of 2900 rpm. It has an internally coupled filter and aspirator that sucks flour (dust) particles to prevent environmental pollution. Grated pulp was dewatered in a screw press (Tropical Development Engineering Company) while pelleting was carried out in a pelleting machine (B & T Ltd, Ibadan) incorporated with a diesel or kerosene fired steam boiler.

Sample Preparation

Three methods were used to prepare the pellet samples for this study.

Sample A: 50kg of washed roots were weighed and chipped then dried in the cabinet dryer until it attained a moisture content of 12% having been allowed to equilibrate at a temperature of 80^{o}C. The samples were allowed to cool then milled into flour and conditioned with clean water to about 22% moisture content and divided into two equal portions. One portion was fed gradually into the pelleting machine accompanied with steam at a temperature of 160^{o}C and atmospheric pressure of 4 KPa to produce hard pellets which were sun dried to

9% moisture content. This method involving chipping, drying, milling, pelleting with steaming will be referred to as CDMP-S.

Sample B: The second portion was pelletised without steaming to produce soft pellets also sun dried to 9% moisture content. This will be referred to as CDMP.

Sample C: 20kg of the washed cassava roots was grated into fine pulp, dewatered to 38% moisture content in the screw press and then pelletised with steaming (160^{o}C and atmospheric pressure of 4 KPa) to produce hard pellets. The pellets were sun dried to 9% moisture content. This will be referred to as GDWP-S.

Uniformity Index of Pellets

The uniformity index was determined to obtain the degree of variation of individual pellet dimension from the generally acceptable dimension. Sixty pellets were selected at random from each of the three samples. The length and diameter were measured using a measuring rule and a micro-meter screw gauge. The mean and standard deviation of the sixty representative samples were computed for each.

Pellet Durability Index

Samples of the pellets processed were stored in a polythene bag for 90 days to monitor the deterioration in terms of conspicuous mould growth. The indices used for measuring handling and storability stability in terms of strength are durability index (N) which is the ability of the pellet to withstand handling stress i.e. degree of wholeness retention and friability (F) of the pellets being the quantity of particles scrapped off during handling i.e. fines particles obtained in the product after handling and transportation. A laboratory durability-testing machine designed and constructed as specified by the ASAE S269.2 rotating at 60 rpm similar to the tumbling box testing machine was used. Having recorded the initial weight (W_i), of a set of 5 pellets were placed in the box and the machine operated for 2 minutes after which their final weight (W_f) was recorded. The durability/friability of the pellets was expressed as the percentage of the final weight to the initial weight. These were calculated from

$$N(\%) = \frac{W_F}{W_I} x100 \qquad (1)$$

$$F(\%) = \frac{W_I - W_F}{W_I} x100 \qquad (2)$$

where N is the Durability of Pellets (%) and F is the Friability of Pellets (%).

Proximate Composition and Cyanide Content of Pellets

The proximate composition analyses were conducted to evaluate their actual nutritional contents as affected by the processing methods. The various chemical compositions were determined using the methods of analysis of the Association of Official Analytical Chemists, AOAC, (1980) and the tests were carried out in the Department of Human Nutrition, University of Ibadan, Nigeria. These include: Carbohydrate content by difference method, Crude Protein content by Kjeldahl process, Fat content by Soxhlet continuous extraction method, Ash content and Crude Fibre. The cyanogenic glycosides (HCN) content was also determined by the Argentimetric titration method.

RESULTS AND DISCUSSIONS

Uniformity Index of Pellets

The results of the mean and standard deviation of 60 representative samples of pellets produced from each of the three methods for length and diameter are as presented in Table 2. The length of the pellets from; CMDP-S, CMDP and GDWP-S have mean and standard deviation of 2.81 cm and 0.40, 2.23 cm and 0.38 and 2.74 cm and 0.40 respectively. The average lengths of the pellets from the two methods which produced hard pellets are close while the soft pellet from CMDP is shorter. This obviously can be attributed to the strength of the pellets as a result of gelatinization of starch by heat from steaming serving as a binding agent. However the lengths of the three samples fall within the standard specified length of 2.0 - 3.0 cm for pellets with the low standard deviation.

The mean and standard deviation of the diameter are 0.76 cm and 0.04, 0.73 cm and 0.04, and 0.67 cm and 0.05 respectively. The trend in the variation of the diameters is similar to the length but with low standard deviation and are within the standard specified diameter of 0.8 cm for pellets.

Table 2: Length and Diameter of Pellets from CMDP-S, CMDP and GDWP-S

	CMDP-S		CMDP		GDWP-S	
	Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)
Mean	2.81	0.76	2.23	0.73	2.74	0.67
SD	0.40	0.04	0.38	0.04	0.40	0.05

Pellet Durability Index

The stored samples (9% mc) were found to be in good condition (without any sign of deterioration) after the 90 days of storage in a packaging envelope. It should be noted that microbial tests were not performed on the samples but were only examined for physical changes. They are also free from any objectionable odour.

In Table 3 the results of the percentage durability and fines from each of the three methods are presented. The results show that CDMP-S has the highest average durability index of 99.8% and lowest average volume of fines (particles) of 0.2%. This implies that it has the highest ability to withstand wear and damage under transportation and handling stress resulting in highest wholeness and least fines. These tendencies are as a result of the high packing density of the pellets brought about by the fine particle sizes of the flour that was used to produce them as well as the presence of a binder in the sample. The binding was brought about by the gelatinization of starch as a result of heat from steam.

The figures are similar to those of GDWP-S having an average of 99.4% durability and 0.6% fines. Though the roots used were grated and not milled, it still turned out to have a very high durability index and minimal volume of fines implying that it can equally withstand damage during transportation, handling and preservation. Similarly, the gelatinisation as a result of the steaming produced a strong binding force between the grated particles. The relatively larger particle size of grating to milling may be the responsible factor for the slight difference in the durability index.

CDMP sample, has the least average durability index and highest volume of fines of 98.8% and 1.2% respectively, of the three samples. This is as a result of the loose nature of the particles that formed the pellets brought about by the non-application of steam to the sample which otherwise would have stimulated the formation of starch gel to act as a binder on the particles.

Table 3: Percentage Durability and Fine from CMDP-S, CMDP and GDWP-S

	CDMP-S		**CDMP**		**GDWP-S**	
S/N	**Durability (%)**	**Fines (%)**	**Durability (%)**	**Fines (%)**	**Durability (%)**	**Fines (%)**
1	99.8	0.2	98.3	1.7	99.8	0.4
2	99.9	0.1	98.6	1.4	99.1	0.9
3	99.9	0.1	99.2	0.8	99.3	0.7
4	99.8	0.9	99.0	1.0	99.4	0.6
5	99.6	0.4	99.0	1.0	99.6	0.4
Mean	**99.8**	**0.2**	**98.8**	**1.2**	**99.4**	**0.6**

It should be noted that the elimination of the first drying process in GDWP-S compared to CDMP-S led to a savings of about eight hours of production time. This when compared to the difference in the strength shows that GDWP-S has an advantage over CDMP-S. However Both CDMP-S, the conventional process of producing pellet and GDWP-S, the modified process, have very low rate of fine formation as a result of steaming. This satisfies the requirements of livestock producers who are concerned with the direct measurement of fines (Khajarern and Khajarern, 2003) as well as the international market that is concerned with the quality on delivery. These results revealed that the samples have these capacities of commanding a high market value with the high durability index and very low fine formation.

Colour and Appearance of Pellets

Visual observation of the three samples of cassava pellets showed that they are all brown in colour though having different shades of brown that are not different from each other (Figure 2). Samples from CMDP-S and GDWP-S are darker in colour than the CMDP samples. However they were subjected to image analysis by computer vision through a histogram analysis of the grey scale of the picture elements (pixels) using a programme written in FORTRAN based on the principle of image processing to confirm the significant difference in the brownness observed visually. The results of the histogram analysis are as presented in Figure 3 a, b and c. There is a sharp contrast between CMDP and the other two which showed similar distribution. Lightness is indicated by a higher distribution or peak spreading towards the extreme right.

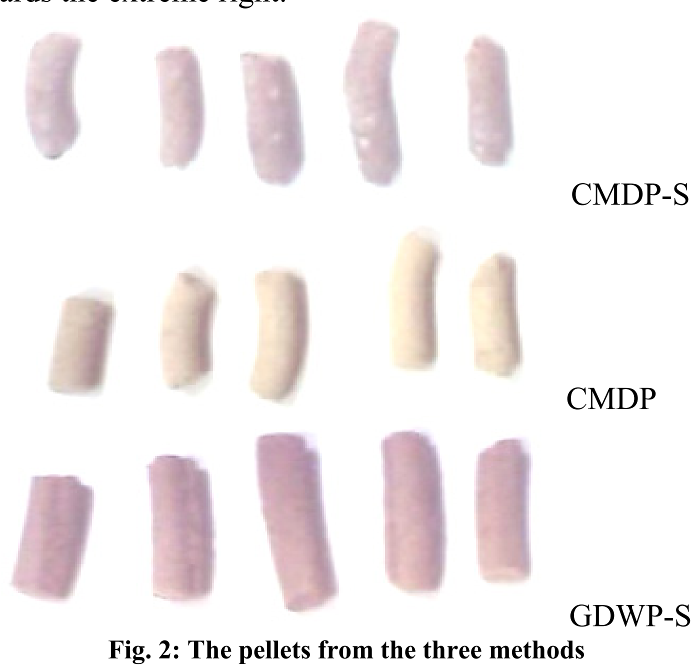

Fig. 2: The pellets from the three methods

The dark brown colour of samples CMDP-S and GDWP-S is as a result of the action of heat from steam causing the gelatinization of starch thus darkening the colour. This is in accordance with the official standard colour for pellets, relatively dark brown as recommended by FMST (2003). CMDP with no heat applied retained the original colour of flour that was used to produce it. Physical touch of the pellets showed that they are firm and have a smooth surface texture.

Proximate Composition of Pellets

The results of the proximate analysis carried out on the pellet samples are as presented in Table 4. GDWP-S retained the highest amount of carbohydrate and contained the least quantity of the other nutrients and thus can be used mainly as a source of energy. It equally retained the least amount of cyanogenic glycosides which is as a result of enzymatic hydrolysis that occurred in the sample during dewatering process leading to the liberation of cyanogenic acid (HCN) from the sample, rendering the dried pellets safe feed for all classes of livestock.

Production Process

One of the conventional production processes for cassava, the first drying operation in chips production was eliminated and replaced with short duration grating and dewatering in the production process for GDWP-S before pelleting. This was found to result in a reduction of approximately 8 hours of processing time with a product which satisfy the export requirement reported earlier i.e. colour, dimension and strength requirements.

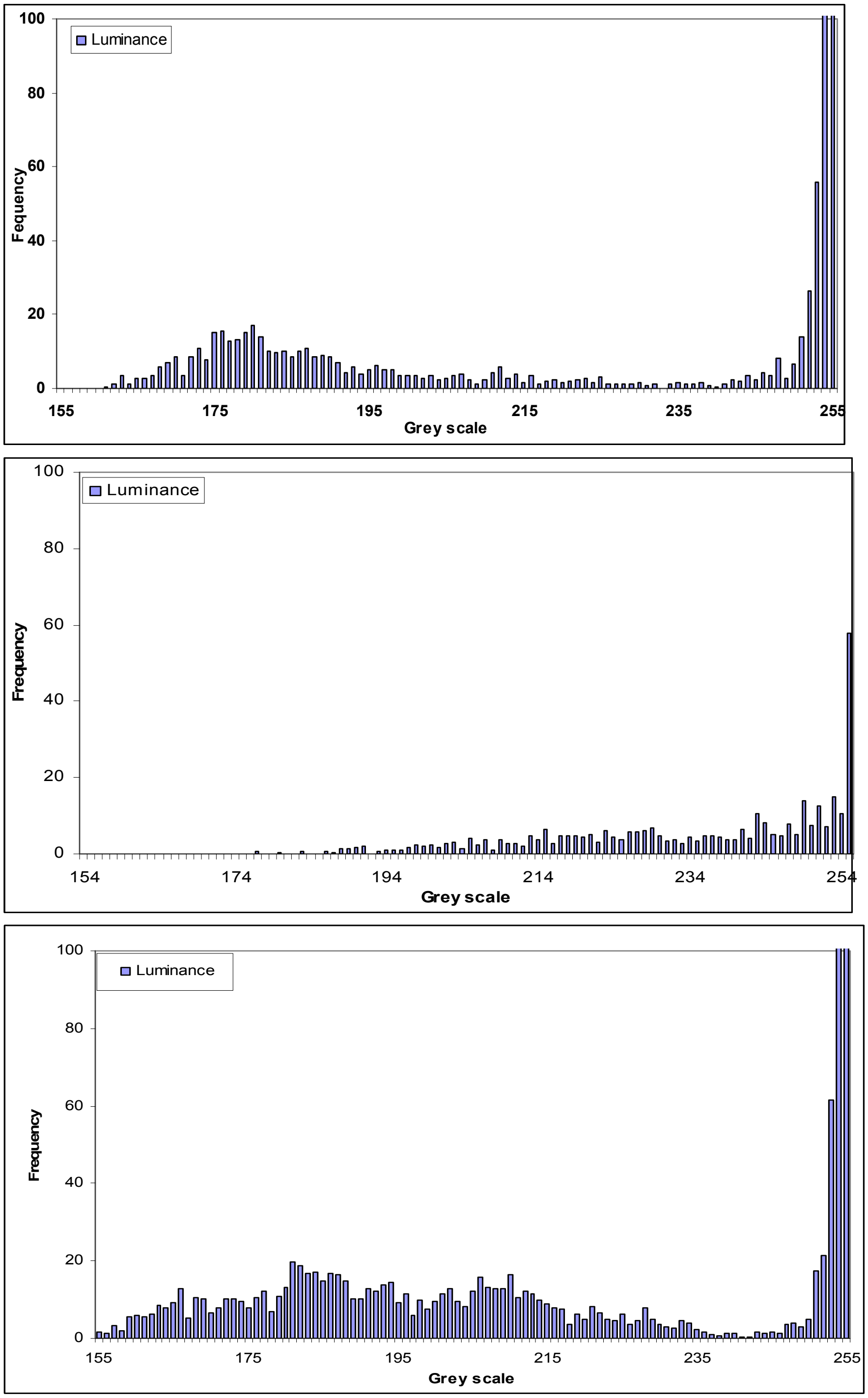

Figure 3. Colour Histogram (a) CDMP-S (b) CDMP and (c) GDWP-S

This time gained, in addition to reduced cost of production, quality retention and increased productivity, if properly harnessed and utilized for efficient training and maintenance of man and machine, will reduce wastage due to rot and decay and go a long way in determining the pace of the nation's agricultural development.

Table 4. Proximate Composition of Pellet from CDMP-S, CDMP and GDWP-S

	CDMP-S	CDMP	GDWP-S
Moisture Content (%)	9.5	9.0	9.7
Crude Protein (%)	4.6	4.2	2.9
Ash (%)	2.4	2.7	2.2
Fat (%)	0.6	0.7	0.2
Crude Fibre (%)	3.4	3.4	3.6
Carbohydrate (%)	82.9	83.4	84.5
CyanogenicGlycosides mg/100g Sample	14.2	14.3	10.1

CONCLUSION

This study has been able to show that the elimination of energy demanding and time consuming unit operations in pellet production and substituting with a modified process has resulted in the production of an internationally acceptable and commercially rewarding cassava pellet. The modified process having reduced the processing time by about eight hours will in addition to the resulting increased production and cost saving encourage and attract small-scale farmers, processors and youths to take up the business of pellet production. The products are also good sources of energy, possessing high carbohydrate content and are safe as livestock feed as a result of their very minimal cyanide (HCN) content, brought about by the positive effect of the process on the product. This will go a long way to help in job creation, economic empowerment and poverty alleviation which are tools in boosting the availability of the pellets for the export market in the developing countries. This will place cassava in its place of pride as a major foreign exchange earner as more roots will be converted to pellets within a short period of production time. In order to determine the actual contribution of the modified process GDWP-S to the reduction of production cost and product quality there is a need for further studies on the timing and energy requirement of each unit operation of the production process.

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