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Estimation of the Material Losses and Gari Recovery Rate during the Processing of Varieties and Ages of Cassava into Gari

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Abstract: Different varieties of cassava were processed into gari to determine the material losses and the rate of gari yield as they are affected by the age of maturity, varietal traits and the processing method and equipment. The varieties were harvested at the ages of 10, 12 and 14 months, respectively. The study showed that varietal differences and age at harvest of cassava roots have notable influences on the average yield of gari. Older cassava roots generally recorded higher gari yields. The material losses also varied across the unit operations. The average losses occurring independently at the various processing stages were: peeling losses, 27.87%; grating losses, 3.95%; dewatering losses, 24.42%; sifting losses, 2.37% and roasting losses, 18.29%. An average overall material loss of about 77% with gari yield of 23% of the fresh tuber weight were recorded. This translates into an average garification rate of 0.23 (23%) of the test equipment and processing method. This factor provides a numerical index for comparing the efficiencies of alternative gari processing methods and equipment in terms of the rate of gari yield.

Key words: Losses, gari, yield, garification rate

INTRODUCTION

Cassava is one of the most important staple foods grown in tropical Africa. It has gained popularity in sub-Saharan Africa because of its appreciated role as a food security crop (Oduro and Ellis, 2000). Since, it is potentially able to provide more food cal ha^{-1} than most crops, it is being looked upon as the main hope for combating human starvation in the sub-region. Unfortunately, the food security potential of cassava is negated by the vulnerability of the crop to deterioration shortly after harvest, limiting its contribution to incomes. The roots and leaves also contain various amounts of cyanide, which at high levels, are toxic to both humans and animals. Therefore after harvest, cassava has to be quickly converted into suitable forms of low cyanide levels with longer and stable shelf life (Asiedu, 1989; Opara, 1999). The processing of cassava into various forms that combine the advantages of diversity, nutritional value and convenience of use is further means of promoting its consumption among different strata of the society (Oduro and Ellis, 2000).

The various derivatives into which fresh cassava roots can be processed are unlimited. By far its processing into a fermented, dried, granular food product called gari is more popular in sub-Saharan Africa than other derivatives (Asiedu, 1989; Opara, 1999). In Ghana for example, gari processing is becoming a fast expanding enterprise, providing employment and income generation opportunities for many farmers and commercially oriented individuals in the rural economy.

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Traditional cassava processing into gari is however, very labour intensive and productivity is often too low to justify the investment of labour, time and money. Also, the yields from many indigenous processing methods are often of poor quality, further reducing their market value and the profitability of the industry. A wide array of indigenous practices and technologies exist in traditional gari processing with only a few of the unit operations mechanized to some extent, mainly to reduce the enormous drudgery involved. Improvement of cassava processing techniques would therefore greatly increase labour efficiency, incomes and living standards of cassava farmers and the urban poor, as well as enhance the shelf-life of the product (Hahn, 2006). Engineering interventions to improve the industrial process is often by way of reducing drudgery and maximizing gari yield through the mechanization of the unit operations with appropriate machinery and by the use of improved stoves to maximize energy efficiency and improve the working conditions of the roasting operation.

In an effort to maximize gari yield in a given processing system, there is the need for detailed process analysis in order to identify the various factors accounting for material losses and to subsequently re-design the process to reduce losses. As a first step, the mass balance for each unit operation and the entire process must be determined. Subsequently, the garification rate (i.e., the rate of cassava conversion into gari) associated with the processing system has to be determined to provide a numerical index that can be used to estimate the gari yield from any given quantity of fresh tubers. With this numerical index, alternative processes or the effect of process variations can be compared. This knowledge is invaluable for development and evaluation of new processing technologies.

Therefore, the purpose of this study was to set out a standard measure to quantify the losses occurring at the various processing stages and then determine the garification rate associated with a common traditional gari processing method using a set of standard equipment.

MATERIALS AND METHODS

Background of Traditional Gari Processing Equipment and Method

Traditional gari processing is basically a manual operation involving 10 basic steps with some variations in the processing details in different resource areas. The processes are peeling, washing of peeled tubers, grating, sacking of grated pulp, dewatering, fermentation, sifting, roasting, sieving and cooling in that order (Asiedu, 1989). The range of equipment for cassava processing are presented by Foodnet (2002).

Peeling and Washing

Peeling of the harvested tubers may be done in the farm to reduce the bulk of material transported home. On the other hand, the fresh tubers may be transported to a peeling bay at home. Peeling involves the removal of the outer cortex, the neck and the small tapering end. The sizes and shapes of cassava tubers differ tremendously, making the peeling process difficult to mechanize and therefore, it is usually done manually with a knife (Asiedu, 1989). Manual peeling requires little technical knowledge and is less risky. It is however, a laborious process, requiring about 1 h for one person to peel 25-37 kg (Opara, 1999). The peeling rate however, depends on the skill of the individual. After peeling, the roots are thoroughly washed in a basin of clear water.

Grating

Washing is followed by grating or rasping of the peeled tubers into fine dough. Grating raptures the tissues and brings together the differentially compartmentalized substrate (cynogenic glucoside) and enzyme (Linamarase) to react and release toxic hydrogen cyanide, which can subsequently be removed (Asiedu, 1989). The greater the extent of cellular damage, the greater the interaction of the two and the greater the subsequent cyanogens removal.

Grating is an energy intensive process and may be done manually or by use of an engine or motor-driven mechanical grater. The manual grater consists of a perforated rectangular grating sheet fixed upon two wooden frames on the opposite longitudinal edges and bowed in the middle so that, the jagged ends of the perforations are outwards. The operator rubs the peeled cassava tuber briskly over the jagged ends, which rasps and reduces the tuber into grates. Recent developments have also produced pedal types of manual rolling graters. In this version, the grating sheet is wrapped over a cylindrical drum, which can be revolved by pedaling or cranking.

Mechanical engine or motor-driven graters offer more intensive advantages than manual graters in terms of capacity and drudgery removal; and have superseded the use of manual graters where resources are available. A number of different kinds of designs have been formulated. They are the disc type and the cylindrical drum type.

The main working component of the cylindrical drum type is a grating drum (rotor or roller) in the form of a hollow cylinder normally made of hard wood or cold-drawn mild steel, having a number of grooves milled longitudinally into rasping blades or the steel sheet may be perforated. The jagged ends of the perforations are responsible for the grating (Asiedu, 1989). The drum is mounted onto a central shaft, which is supported by ball bearings on either side. A pulley is keyed to the shaft at one side and this receives rotary power from the prime mover through a flat belt.

The cylindrical drum is housed in a wooden or metal framework, the top part of which consists of a hopper, with the base slanted towards one side of the drum to form the discharge chute. The hopper may be trapezoidal or oval-shaped to reduce spillage. The lower portion of the housing (just below the drum) extends into the chute through which the grated mass leaves the machine. Between the cylindrical drum and the chute is a clearance adjustment board, which can be moved in or out to vary the clearance between the drum and the lower end of the hopper that leads into the chute. Reducing the clearance results in fine mash whilst increasing the clearance produces medium or coarse mash.

In the disc type, the grating surface consists of a perforated circular galvanized steel sheet mounted on to a circular wooden plate. Together, they sit on a metal plate which in turn, is keyed to a power-driven vertical shaft. A hopper which also serves as a cover for the grating chamber sits on top and is designed to prevent the cassava pieces from spilling over the hopper.

Mechanical graters may be designed into mobile types or may be stationary in fixed installations. A 1.0-5.0 h.p. petrol engine may be used for mobile graters and 5.5-10.0 h.p. diesel engine for stationery graters. Where electricity is available, it is more economical to use an electric motor instead. Power from the prime mover is transmitted to the grating machine through a belt drive. Man-operated graters have grating capacities ranging from 15-25 kg harvest^{-1} while, the capacities of the mechanical power driven types range from 0.5-1.2 t harvest^{-1} depending on the type of machine.

Fermentation and Dewatering

After grating, the wet dough is collected into jute sacks or large baskets and left in a fermentation rack or in the open to ferment for 1 to 5 days depending on the local practices and consumer preferences (Asiedu, 1989). Fermentation allows glucosides (the bound cyanide) to be broken down into soluble hydrogen cyanide (HCN), which dissolves in the water and is subsequently expressed off (Asiedu, 1989). The time it is allowed to ferment affects the gari's color, taste, texture as well as the level of removal of the hydrogenic cyanide content. Generally, a period of 24 h is enough to reduce the cyanide content to a safe level for human consumption.

Dewatering involves the removal of the HCN-dissolved water and some quantity of starch from the fermented dough. Depending on the resources available, a pile of stones or a mechanical screw press may be used. The mechanical screw press is more efficient with less drudgery and is available in two versions-the single screw press and the double screw press. The single screw press consists of a perforated metal cage or basket with a vertical screw and a ram assembly. The fermented dough is loaded into jute sacks and placed in the cage. The ram is screwed down against the sacks squeezing off the water, which exit through the perforations.

The double-screw press works on the same principle but the ram consist of a heavy horizontal press bar, which is screwed down between two vertical screws. Wooden boards are placed over the loads to distribute the pressure over a large contact surface and to avoid the bursting of the jute sack. De-watering is complete in about a day and since only about 24 h is also required for fermentation, most traditional practices perform both fermentation and de-watering together.

Sifting

Dewatering leaves a damp cake of cassava dough, which must be pulverised and the ungrated particles sieved off. A woven mesh made of woven splinters of cane is used for the sifting. It is placed over a wooden box and screened so that the fibre and ungrated lumps are trapped above as the loose, damp flour is collected in the box.

Roasting

Roasting, (also called frying) is a most important step and requires a lot of skill to produce gari of the desired quality. It is mainly a dehydration process during which the sifted flour is subjected to heat treatment on a hot surface to dry the flour. The hot surface is provided by heating an open earthenware or iron pan gently from below. A small quantity of the wet flour is spread thinly in the pan and a portion of calabash is used to stir continuously to distribute the heat fairly within the mass and to avoid the burning of the flour.

In the process, the starch within the flour undergoes partial gelatinization, a process during which the starch granules absorb water, swell and undergo structural changes. Gelatinization of starch begins at a temperature of about 60°C and is complete at about 73-81°C and is followed by drying from a moisture content of about 45 to 10-15%. The finished product is crispy with a yellowish-brown color and a characteristic taste.

Estimation of the Material Losses and Gari Recovery

Gari processing, as described above, involves both mass and heat transfer. Material losses during gari processing may be defined as the mass transfer from the original product during processing. It occurs at all stages of processing in the form of dry matter losses (peels, dough, fibre, etc.) the removal of liquid starch, water and moisture evaporation at the different stages. The loss at each stage of processing was found by finding the difference in the weight of material recovered before and after the stage. This was then calculated as a percentage of the initial weight of the fresh cassava. On this basis, the individual losses were calculated.

Plant Material

The test crops consisted of a local cassava variety and different improved varieties harvested at different ages of maturity (10, 12 and 14 months) from the Asuansi Research Station in the Central Region of Ghana. The experiments were conducted in January, 2004 and March, 2005 in the Agro-Processing laboratory of the School of Agriculture, University of Cape Coast. The main limitation to this experiment was our inability to obtain all the varieties at all the different ages for testing since, the crops were not directly under our control and were also cultivated for other research interests.

Equipment

The following equipment were used to estimate the material losses and gari yield from the various cassava varieties.

Peeling Knifes

- A 3.5 h.p. engine-driven cassava grater (MK1 model) with a capacity of up to 1 t harvest^{-1}. Designed by the Postharvest Engineering Unit of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, this model has been widely promoted in West Africa among IITA partners as a better alternative to the local models used throughout West Africa. The grating surface is a perforated metal sheet wrapped on a cylindrical drum. A unique feature of this design is the oval-shaped hopper to reduce material spillage
- A double screw press
- A rectangular wooden box sifter
- An insulated-walled chimney stove with an open iron pan on the fire box

Peeling Losses (L_p)

Let, W_1 is the initial weight of fresh cassava tubers, W_2 is weight of peeled tubers. Then, W_1-W_2 represents the peeling losses:

$$\text{The percentage peeling losses } (L_P) = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

Grating Losses (L_G)

Let, W_3 is weight of the collected wet dough from the grater. Then, W_2-W_3 represents the grating losses:

$$\text{The percentage grating losses } (L_G) = \frac{W_2 - W_3}{W_1} \times 100 \quad (2)$$

Fermentation/Dewatering Losses (L_D)

Let W_4 is weight of dough after fermentation and dewatering. Then, W_3-W_4 represents the fermentation/dewatering losses:

$$\text{Percentage fermentation/dewatering losses } (L_D) = \frac{W_3 - W_4}{W_1} \times 100 \quad (3)$$

Sifting Losses (L_S)

Material losses during sifting are mainly due to spillage, the residual fibre and the ungrated masses that are retained over the sifter. These may be given out as animal feed. Let, W_5 is weight of the sifted flour. Then, W_4-W_5 represents the sifting losses.

$$\text{Percentage sifting losses } (L_S) = \frac{W_4 - W_5}{W_1} \times 100 \tag{4}$$

Roasting Losses (R_L)

Material losses encountered at the roasting stage include evaporation of moisture into the atmosphere as well as spillage of particles as the operator stirs through with a portion of calabash. Let, W_6 is weight of roasted flour (gari). Then, W_5-W_6 represents the roasting losses.

$$\text{Percentage roasting losses } = \frac{W_5 - W_6}{W_1} \times 100 \tag{5}$$

Determination of the Percentage Gari Yield or the Garification Rate

The total loss for each variety was obtained by adding all the losses in Eq. 1-5. The total amount of gari obtained, expressed as a percentage of the fresh cassava roots is thus equal to 100 minus the total percentage losses for each cassava variety. The mean values of the losses were also determined.

From the results obtained a relationship between the initial weight of fresh cassava tubers and the yield of gari was established from the relation:

$$W = W_1 K$$

Where:

W = Weight of gari yield

W_1 = Initial weight of cassava tubers

K = Constant (garification rate)

From knowledge of the garification rate associated with a given processing system, an entrepreneur can estimate gari yield from a quantity of fresh cassava roots purchased.

RESULTS AND DISCUSSION

The percentage material losses at the different stages of processing and the final gari yield from the different varieties harvested at different ages are shown in Table 1. Average peeling loss was 27.87%, grating loss 3.95%; fermentation/dewatering loss 24.42%; sifting loss 2.37% and roasting loss 18.29%. The total loss was recorded to be 76.90% with average gari yield of 23.10% of the initial weight of the fresh tubers.

The general trend also showed that older cassava roots gave higher gari yields than younger roots. The different varieties also showed difference in the gari yields.

The results from the above experiment give an indication that age and variety have influences on the yield of gari. Comparing those same varieties harvested at different ages, it was noted that UCC 504 harvested after 12 months yielded a higher percentage (20.60%) than the same variety harvested after 10 months, which yielded 18.24% of the fresh tuber

Table 1: Percentage material losses for the different unit operations for different cassava varieties harvested at different ages

Cassava variety	Age at harvest	Peeling losses	Grating losses	Dewatering losses	Sifting losses	Roasting losses	Total losses	Gari yield
		----------	----------	----------	-----(%)-----	----------	----------	----------
UCC 153	10	21.75	7.67	26.33	1.83	19.25	76.83	23.17
UCC 265	10	26.92	4.75	23.33	2.00	19.75	76.75	23.25
UCC 504	10	33.33	9.20	19.20	2.20	17.83	81.76	18.24
UCC 505	10	26..42	6.50	20.10	3.33	20.75	77.10	22.50
UCC 514	10	24.50	9.33	22.20	3.80	18.67	78.50	21.50
Mean		26.58	7.45	22.23	2.63	19.25	78.14	21.86
Local	12	26.33	3.78	18.60	2.28	22.12	73.11	26.89
UCC 504	12	33.70	6.70	21.90	1.70	15.40	9.40	20.60
UCC 505	12	28.20	1.20	24.70	3.80	18.40	76.30	23.70
UCC 506	12	29.60	1.20	30.10	1.50	15.80	78.20	21.80
UCC 007	12	27.50	2.50	27.50	4.00	14.30	75.80	24.20
UCC 11	12	26.80	6.10	31.70	1.20	14.20	80.00	20.00
UCC BB	12	27.90	1.50	25.90	1.80	19.40	76.50	23.50
Mean		28.55	3.20	25.44	2.33	17.07	76.59	23.41
UCC 506	14	37.20	0.60	31.70	1.10	13.10	83.70	16.30
UCC 007	14	24.30	1.70	23.90	2.40	21.70	74.00	26.00
UCC 11	14	27.80	2.60	28.10	0.90	18.20	77.60	22.60
UCC BB	14	24.60	0.00	24.00	4.00	18.90	71.50	28.50
UCC 336	14	26.60	1.10	20.30	2.30	20.90	73.50	26.50
Mean		28.50	1.20	25.60	2.14	18.56	76.00	24.00
Overall Mean		27.87	3.95	24.42	2.37	18.29	76.90	23.10

Source: Boahen (2004) and Duah (2005)

weight. A similar trend was observed for UCC 505 harvested at 12 and 10 months, respectively and for varieties UCC 007, UCC 11 and UCC BB harvested at 14 and 12 months, respectively. This general trend may be accounted for by the higher dry matter accumulation and lower moisture contents in older crops. The only variety which deviated from this trend was UCC 506, where the 12 month old crop yielded higher gari than the 14 month old crop. This could be because UCC 506 may have over matured by 14 months. According to Opara (1999), during growth season, both root and starch production increase rapidly to their maximum value and they decline afterwards.

The material losses also varied across the stages of operation as indicated in Table 1. On the average the greatest losses were recorded at the peeling, dewatering and roasting stages while grating and sifting losses were the lowest recorded. Peeling losses averaged about 27.87%; grating losses averaged 3.95%; dewatering losses, 24.42%; sifting losses, 2.37% and roasting losses 18.29%.

Peeling basically requires the removal of the outer cortex which contains a high concentration of HCN, the stumps, the tapering ends and very often, rotten portions. But alongside, some desirable dry matter is lost. The amount of these materials lost therefore depends largely on the cultivar, the quality of the fresh cassava tubers and the peeling efficiency. The peels alone make up about 10-15% of the fresh weight but according to Opara (1999), hand peeling losses average 25-30%, with higher mechanized peeling losses of about 30-40%.

Losses occurring in the mechanical grater are attributable to spillage from the hopper as a result of vibrations. It also includes dough held between the jagged ends of the perforations, those sticking to the surface of the chute and lumps of ungrated cassava locked up in the corners of the machine. Firmly bolting the grater on the foundation floor to reduce vibrations or appropriate design of the hopper to contain the materials would provide a measure of control over greater losses.

Material loss at the dewatering stage is mainly the removal of HCN-dissolved water and starch from the product. The quantity of water expressed depends on the moisture content of the cassava, which is also a function of its age and variety. Varieties of lower moisture contents tend to record lower losses at this stage. All things being equal, older crops with higher dry matter accumulation should also have lower dewatering losses. Following this rule, one would expect dewatering losses for the younger crops to be significantly higher than older crops. But the results showed consistently lower dewatering losses for varieties harvested at older ages than their corresponding varieties harvested at younger ages. This inconsistency may be explained by the different seasons of harvest. As noted by Hahn (2006) during the early rainy season, the dry matter content of roots is usually lower than in the dry season.

Sifting losses are more associated with the operator skill to reduce spillage whilst roasting losses also depend on the moisture content as well as operator skill.

The mean gari yield associated with the test processing system ranged from about 21-24% of the initial weight of fresh tubers, averaging at about 23%. This translates into an average garification rate of 0.23. Since, different cassava varieties harvested at different ages were passed through the same system of equipment and the same processing method, it may be assumed that the effects of varietal differences and age of the cassava roots on the garification rate (K) were neutralized by each other so that the average garification index of 0.23 can be said to be representing the efficiency of the processing system. All other factors being equal, this factor K can be said to be an attributable property of the processing equipment and may be used as a numerical index to compare the efficiencies of different processing systems in terms of gari yield; that is, the higher the garification index K, associated with a system, the higher the potential gari yield.

CONCLUSIONS

It has been established from this study that three main factors account for the material losses and consequently, the expected gari yield from any given set of processing equipment and method. They are the varietal characteristics, the harvesting age and season and what has been established as the garification rate or index which is an inherent property of the processing system.

- Different varieties have different dry matter and moisture contents and hence different amount of peels, starch and moisture that are removed from the roots during processing into gari. Moisture content also depends on the age and season of harvest. At high moisture content more water will have to be expressed reducing the remaining useful weight. Generally, older cassava roots yield a higher percentage of gari than those harvested too early
- Material losses are highest at the peeling, dewatering and roasting stages and therefore, improvement of the gari yield should target the development and use of cassava varieties with lower peels and moisture content
- The garification rate associated with a set of processing equipment provides a bench mark for comparing the efficiencies of different processing equipment. It may be improved by detailed analysis of the various unit operations for the material losses in order to reduce the losses at the critical stages

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