Characterization of flour obtained from waste of cassava minimally processed

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The minimal processing of cassava generates a lot of waste, comprising of shells and pieces that do not meet the standards of minimally processed products. Thus, the study aimed assess the influence of processing steps of waste from cassava to reduce or eliminate the levels of cyanogenic glycosides on the use of waste in the production of flour and product development. The residues were washed in running water, selected, sorted, sanitized, centrifuged, crushed, pressed and dried at 90 ° C. Waste in nature and the flours were analyzed for physico-chemical and microbiological. For microbiological analysis, the steps of sanitization and drying were effective to obtain flour with low concentration of microorganisms. Regarding the physical-chemical waste in nature and the flour had low lipid, ash and protein and high percentage of carbohydrates. The operations of grinding and pressing of the residues provoked significant increase in the tenor of starch and significant decrease in the tenor of total cyanide, total acidity and browning index. Thus, it was found that the processing of cassava waste was effective in reducing total cyanide, thus making it possible that these residues are utilized in food formulations.
Key words: Cyanogenic glycosides; crushing; pressing; drying

No processamento mínimo da mandioca gera-se uma grande quantidade de resíduos, que compreendem entre cascas e pedaços que não correspondem aos padrões dos produtos minimamente processados. Assim, o trabalho teve como objetivo avaliar a influência das etapas de processamento dos resíduos da mandioca de forma a reduzir ou eliminar os teores de glicosídeos cianogênicos para a utilização desses resíduos na produção de farinhas e desenvolvimento de produtos. Os resíduos foram lavados em água corrente, selecionados, classificados, sanitizados, centrifugados, triturados, prensados e secos a 90°C. Os resíduos in natura e as farinhas foram analisados quanto às características físico-químicas e microbiológicas. Em relação às análises microbiológicas, as etapas de sanitização e secagem foram eficientes para a obtenção de farinhas com baixa concentração de microrganismos. Em relação às análises físico-químicas os resíduos e as farinhas apresentaram baixo teor de lipídeos, cinzas e proteínas e elevada porcentagem de carboidratos. As operações de trituração e prensagem dos resíduos provocaram aumento significativo no teor de amido e diminuição significativa no teor de cianeto total, acidez total e índice de escurecimento. Assim, verificou-se que o processamento dos resíduos da mandioca foi eficaz na redução de cianeto total, tornando possível que estes resíduos sejam aproveitados em formulações alimentícias.
Palavras-chave: Glicosídeos cianogênicos; trituração; prensagem; secagem

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1. INTRODUCTION

The roots of cassava (*Manihot esculenta* Crantz) are very perishable when compared with other root crops. This fact has led to large post-harvest losses, limiting the marketing period of the roots, which have provided many losses, a burden, so this culture. Within this context, minimally processed cassava (MMP) has emerged as an alternative marketing to improve the conservation of the root and increase their shelf life (ALVES *et al*., 2005). Furthermore, the minimal processing of cassava food provides a more practical, ie, stripped, cleaned and sanitized, ready to be used (LUND *et al*., 2005).

A technological problem of minimal processing of cassava is the large amount of waste generated, especially in the selection and peel (SILVA *et. al*., 2003). However, these residues, as well as other agricultural products, are usually discarded or used without treatment for animal feed or as fertilizer (LAUFENBERG *et al.*, 2003).

One form of action, with respect to the use of waste, is to seek economic and viable uses for the inevitable industrial residues generated. Where possible, the final residue should be in the raw material for a new process, constituting a second transformation. According to Laufenberg *et al*. (2003), the waste may contain many substances of high added value and can be converted into commercial products or raw materials for secondary processes employed if a suitable technology. Waste of minimal processing of cassava can be processed into flour for use in food formulations, as compared to other agricultural products, they present a large energy reserve (PANDEY *et al*., 2000). Therefore, the development of technologies that permit the use of such residues in food is extremely important, since much of the population suffers from serious problems of malnutrition, while daily, tons of food are discarded as waste.

According to Marques *et al*. (2005), derived from cassava products are of paramount importance, especially for low-income populations, because they are excellent sources of nutrients. Flour is one of the main cassava products, and its use is widespread throughout the country as part of the daily meal of most Brazilians, especially in the North and Northeast. Moreover, this food has a high energy, rich in starch, fiber and some minerals such as potassium, calcium, phosphorus, sodium and iron (DIAS & LEONEL, 2006).

Studies aimed at the use of cassava flour in bakery products have demonstrated its use in partial replacement of wheat flour can be made to produce bread with good sensory characteristics and nutritional needs. Marques *et al.,* (2005) found that the replacement of up to 10% of wheat flour by cassava flour did not cause sensory changes that may compromise the use of French bread.

This study aimed to characterize through physical-chemical and microbiological waste generated during cassava processing requirements as well as the development of sustainable technology that enables the production of flour produced from such waste that can be used as dietary supplements.

2. MATERIALS AND METHODS

2.1 Material Plant

The residues of cassava breeding of Rosa cultivar were acquired from a minimum processing unit in the city of Aracaju, SE, and the work has been performed in the laboratory of Food Technology, Federal University of Sergipe. The waste was generated in the selection and peeling of minimal processing of cassava.

2.2 Obtaining the flour of cassava waste

For preparation of the meals varied sure steps of crushing and pressing of waste (Figure 1) with a view to assessing the influence on the reduction of levels of total cyanide and physico-chemical composition of the waste and of the flour. The procedures discussed in this step were: 1 - waste *in nature*; 2 - grinding of waste particles obtained with an average diameter of 1.94 mm without pressing, 3 - grinding of waste particles obtained with an average diameter of 1.94 mm of the mass crushed and pressing, 4 - grinding of waste getting average diameter particles 1.40 mm without pressing; 5 - grinding of waste getting average diameter particles 1.40 mm with pressing and 6 - produced flour. The flowchart of the processing of waste is shown in Figure 1

Residues from cassava processing minimum, after being obtained, were initially washed in running water to remove the excess contaminants, and subsequently selected for removing those unwanted stains and unfit for human consumption. After selection, the materials were weighed and classified according to the type of waste: Cuts and between shell (the cortex) and then immersed in solutions of chlorine at a concentration of 198mg L for 10 minutes and centrifuged for one minute to remove excess water from washing and sanitation. The materials were then ground in a food processor, particles with average diameter of 1.40 mm, stored at controlled temperature (7 ± 2 ° C) for a maximum of 24 hours to the production of flour, as shown in Figure 1.

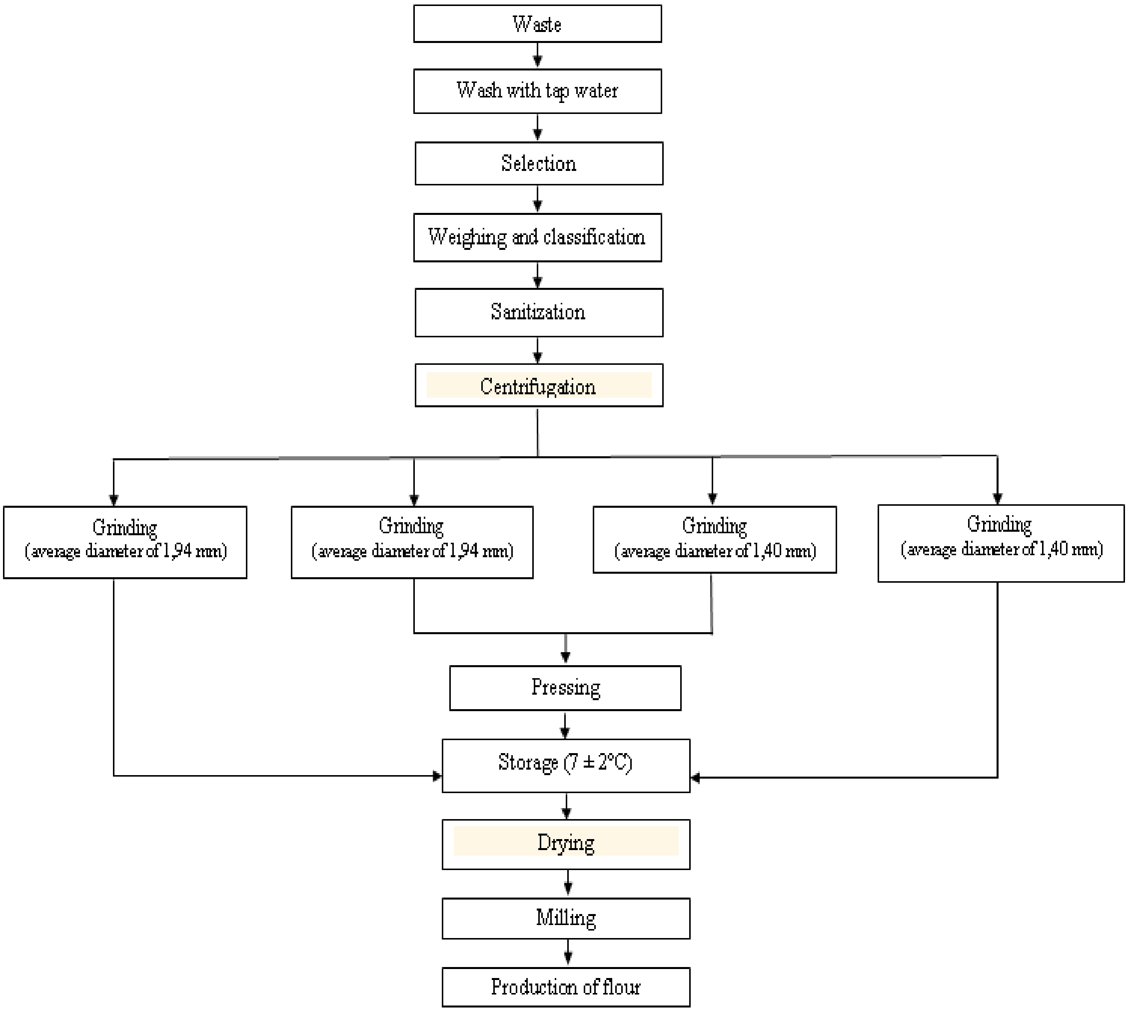

Figure 1. Flow chart of processing of cassava waste for the production of flour.

2.3 Analysis cassava waste *in nature* and waste of flour

Humidity

The moisture content of samples was determined by submitting approximately 1.5 g in a moisture analyzer by infrared, GEHAKA IV 2000.

Ash

The mineral content was analyzed by incineration at 550 ° C in muffle furnace method as described by the Adolfo Lutz, 2005. Expressed in (%) ash.

Lipids

The lipid content was obtained by extraction with cold solvent (methanol/chloroform/water) according to the method described by Bligh & Dyer (1959), modified by Contreras-Guzman (1982) with adjustments and expressed in (%) of lipids.

Protein

The proteins were determined by evaluating the total nitrogen of the sample by the Kjeldahl method, as described by the Adolfo Lutz (2005), using the conversion factor 6.25 and expressed in (%) of crude protein.

Crude fiber

The content of crude fiber was determined by gravimetric method after acid digestion and basic and drying of defatted sample in an oven, and subsequent incineration in muffle furnace (HENNEBERG, 1984). The result was expressed in (%) of crude fiber.

Starch

The starch content was determined using the methodology proposed by CARVALHO *et. al*. (2006). The result was expressed in (%) of starch.

Carbohydrates

Was determined by the difference in accordance with Standards Analytical Institute Adolfo Lutz (1985), in which the content is estimated by difference, subtracting from 100 the sum of proteins, lipids, ash, moisture, crude fiber and starch and the results expressed in (%) of total carbohydrates.

Total cyanide

The analysis of total cyanide described by Bradbury (1991) is the extraction of cyanogenic compounds by the method pyridine and subsequent reaction with chloramine T and isonicotinic acid / barbituric acid and determination by spectrophotometry at 600 nm. The result was expressed in $mg.Kg^{-1}$ fresh weight.

2.4 Review of microbiological

To check the efficiency of sanitization and drying on microbial reduction of the microbiological analysis were performed to assess the presence of total coliform and fecal yeasts and molds and mesophilic aerobic bacteria in the materials in their natural state before and after sanitization and products dry. For this, we used the methodology proposed by Vanderzant & Splittstosser (1992), according to Resolution RDC Nº. 12 of 2 January 2001, the National Health Surveillance Agency (ANVISA). Acidified (PDA). The plates were incubated in an oven at 25 ° C for 5 days.

2.5 Experimental design and statistical analysis

We used a completely randomized design with three replications of each treatment. Data were expressed as means. The results obtained during the experiments were statistically evaluated by analysis of variance, using the Tukey test at 5% significance level, with the help of the Statistica 5.0. (StatSoft, 1999).

3. RESULTS AND DISCUSSION

3.1 *Characterization of waste from cassava processing minimum*

In Table 1 are shown the values of crude protein, moisture, lipid, ash, starch, fiber and carbohydrates of cassava waste *in nature*.

Table 1. Physico-chemical waste from the minimal processing of cassava in natura.

Constituents	RPPC*	REMI**
Crude protein (%)	0,8^{b}±0,06	2,0^{a} ±0,06
Humidity (%)	60,3^{b}±0,17	70,0^{a}±0,17
Lipids (%)	0,3^{b}±0,00	1,1^{a}±0,06
Ash (%)	1,0^{b}±0,00	1,2^{a}±0,06
Starch (%)	17,3^{a}±0,06	10,3^{b}±0,06
Crude fiber (%)	2,1^{b}±0,23	9,1^{a}±0,12
Total carbohydrate ** (%)	18,2^{a}	6,3^{b}

*RPPC * = residue of pieces from the pulp of fresh cassava.; RBPC** = residues between peel fresh cassava.*
**** The determination of total carbohydrate was performed by calculating the difference using the results of moisture, ash, crude protein, crude fat, starch and crude fiber.*
Means followed by the same letter in the same line, do not differ statistically among themselves. We applied the t-test at 5% probability.
Average of three measurements ± standard deviation (δn-1)

There was significant difference between the levels of this protein from the bark (2.0%) and the pieces of the pulp (0.8%) "in natura" (Table 2). The protein content present in the bark of "fresh" was 250% higher than that determined in chunks of pulp (Table 2). This increase may be due to nitrogen fraction that comprises not only the protein, but not the protein, which participates in the nitrogen corresponding to the CN radical linamarin (Cereda, 2001), so that evaluations of the protein between the hull and its other parts that still contains the glycoside, may have influenced and overestimated the existing proteins. Data Sreeramamurthy (1945) showed that gross amount of nitrogen is not extracted with solvents traditionally used in the methodology of the determination of protein and, although a portion of that nitrogen is not extracted protein in nature, the presence of other nitrogen is also likely . The protein content determined in pieces of flesh was found by the approximate Pandey *et. al.* (2000), which was 1.0%. According Oke (1968), the classical methodology used to assess protein, which multiplies the gross nitrogen by a factor is not sufficiently accurate, since it has not been established with a factor value corresponding to amino acids of cassava , using the calculation amount for cereals or other vegetables.

The moisture determined in between the shells and pieces of flesh were respectively 70.0% and 60.3%, which differ significantly (Table 2). The moisture content determined for the waste "in nature" were close to those observed Pandey *et. al.* (2000), which was 65.5%.

The percentage of lipids determined in the waste "in nature" was 0.3 and 1.1% for the pulp and pieces of bark, respectively, which differ significantly (Table 2). For the lipid content, the values determined in the waste "in nature" were higher than that determined by Pandey *et. al.* (2000), which was 0.2%. According Cereda *et. al*. (2003), the root of cassava is low in fat, with an average grade of 0.30%.

The levels of ash found in the samples "in natura" were low, with chunks of flesh and peel of presenting, respectively, a content of 1.0% and 1.2% (Table 2). According Pandey *et. al.* (2000), the cassava residue "in natura" is characterized by a small ash content, which gives, for example, good applicability in bioprocess.

Regarding the contents of total carbohydrates, starch and fiber, there was significant difference in levels in the samples in their natural state, with chunks of pulp containing approximately 289% more total carbohydrate in relation to between shells (Table 2).

The fraction of the corresponding root fibers, it is certainly underestimated by the methodology of fiber, for although clearly fiber, the values found in literature are close to 2.0% fiber (Vitti, 1966), close to the value determined in waste pieces of flesh "in natura", which was 2.1% (Table 2), while the method of detergent is obtained almost ten times more. This study found that the waste from the cassava peel "fresh" was given a value of 9.1% crude fiber (Table

2). These differences are due to the fact that Vitti (1966), Pandey *et. al*. (2000) and Cereda *et. al*. (2003) to determine the composition of the cassava waste generated during the minimal processing, but that generated by manufacturers, which is a fibrous material that contains about 47.0% and 43.0%, bs, respectively, of starch and dietary fiber.

According to the physical and chemical analysis carried out, it was found that residues of cassava are substances containing less than 2% of protein, negligible levels of lipids and poor source of minerals. Thus, residues of cassava can be used in the form of dietary supplements, as there is a major source of carbohydrates.

According Stertz (1997) and Raupp *et. al.* (1999), the compositions of cassava waste differ somewhat because most of the processing is done under poor control conditions and also due to the use of variations of different crops. However, waste from cassava are characterized by high content of starch and the small amount of protein and ash (Pandey *et. al.*, 2000). The results showed certain, therefore, consistent.

3.2 *Influence of processing steps of waste in the levels of cyanide to the meal preparation*

In Figure 2 are shown the levels of total cyanide during processing steps of waste flour from the minimal processing of cassava.

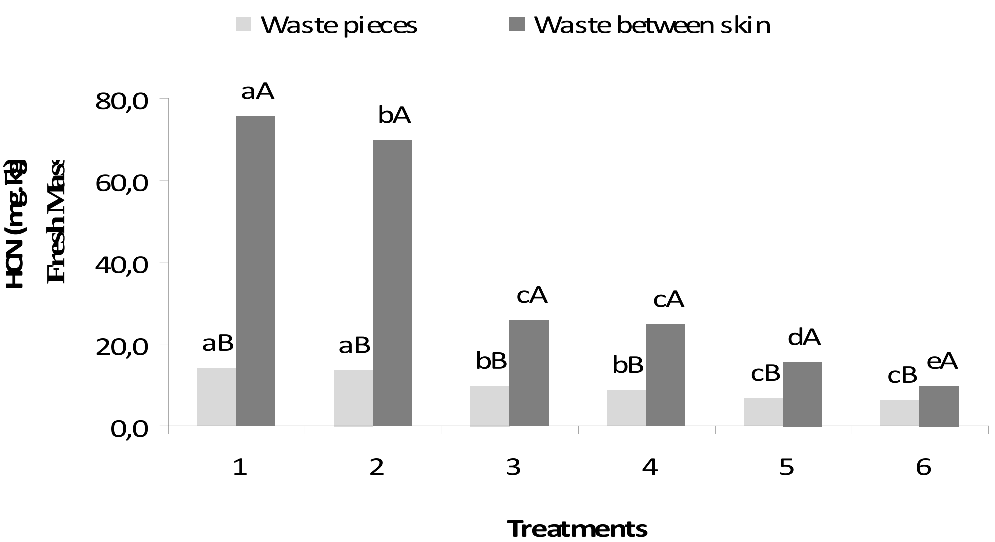

Figure 2. Determination of total cyanide during processing steps of the flour of cassava waste from the processing minimum. (1) residue in nature, (2) grinding of waste particles obtained with an average diameter of 1.94 mm without pressing, (3) grinding of waste particles obtained with an average diameter of 1.94 mm of the mass crushed and pressing, (4) grinding of waste getting average diameter particles 1.40 mm without pressing, (5) grinding of waste getting average diameter particles 1.40 mm with pressing and (6) produced flour. Means followed by lowercase letters to the processing steps and letters to the samples with the same letter do not differ statistically among themselves. We applied the Tukey test at 5% probability.

Figure 2 shows that the residuals of the pieces of bark and in step 1 were 14,2 and 75,6 mg $HCN.Kg^{-1}$, respectively. In step 2, there was reduction in total cyanide in waste of the pieces, which was 13,6 mg $HCN.Kg^{-1}$ for the residues between the hull there was a significant difference, which was 69.8 mg $HCN.Kg^{-1}$ (Figure 2). This decrease is due to disruption of the cells releasing linamarase, which comes into contact with the substrate linamarin, releasing HCN which will be volatilized as a result of processing (CAGNON *et al*., 2002).

Mass pressed, step 3, was also found significant reduction of total cyanide, waste and the pieces of bark (Figure 2). Since, during this process, the content of linamarin, which is soluble in water and HCN formed earlier are mostly dragged along with Manipueira (liquid extracted from the crushed mass during the pressing) (CEREDA, 2003).

The product of flour of cassava waste, and pieces of bark, obtained 6.4 and 9.7 mg $HCN.Kg^{-1}$, respectively, also taking significant reduction of total cyanide. A low dose of total cyanide in cassava waste is caused by the fact that they were dried at high temperature, much of the volatilized HCN present in the mass pressed earlier.

According to the World Health Organization (WHO), the safe level of cyanogen in cassava flour is 10 ppm (FAO / WHO, 1991). The results in Figure 2 is given to such samples, cyanogenic toxicity acceptable for human consumption.

The bark of the cassava contains high levels of cyanogenic compounds, mainly linamarin, which when hydrolyzed by the enzyme linamarase release hydrogen cyanide (HCN), which is potentially toxic to health (CAGNON et al., 2002). According to Motta (1985), the level of toxic agent in the inner bark of the cassava is 320 ppm, and the limit for intoxication is 10 ppm (FAO, 1998).

According Cereda (2003), although most of the glycosides can generate HCN are removed during milling, pressing and drying, there may be residues of toxic compounds, depending on the type of processing employed. Thus, studies are being conducted to verify the possibility of producing flour from the phloem and use them in the formulation of mixed flours for human consumption. Therefore, it is necessary to promote detoxification of the same by appropriate technological processes, for example, pressing and drying.

3.3 *Characterization of flour obtained from cassava waste from the minimum processing*

There was significant difference in the moisture present in the flour and phloem pieces were respectively 5.4% and 7.6% on dry basis (Table 2). These results were close to 5.03% found by SOCCOL *et. al*. (1994) for the flour produced from the waste generated in the cassava starch. The analysis of the moisture content of flour waste showed that the samples are consistent with the limit established by Brazilian legislation (maximum 13%) (BRAZIL, 1995). The difference in humidity between the samples can be explained by the drying process that is subject, in which most of its moisture is removed. During the drying occurs agglomeration of starch granules, larger granules which retain more moisture (Table 2). Moisture is important in the storage of dry foods, with levels greater than 12% can provide microbial growth. The moisture content is related to its manufacturing process, which demonstrates the lack of standardization of the product (CHISTÉ *et al*., 2006).

Table 2. Physico-chemical waste flour from the minimal processing of cassava.

Samples*	Crude protein (%)	Humidity (%)	Lipids (%)	Ash (%)	Starch (%)	Crude fiber (%)	Total carbohydrate ** (%)
FWP	$0,8^{b}\pm 0,00$	$5,4^{b}\pm0,06$	$0,9^{b}\pm0,06$	$0,6^{b}\pm0,06$	$40,8^{a}\pm0,06$	$3,3^{b}\pm0,06$	$48,2^{b}$
FWB	$2,2^{a}\pm 0,06$	$7,6^{a}\pm0,06$	$2,0^{a}\pm0,06$	$1,9^{a}\pm0,06$	$30,6^{b}\pm0,12$	$5,7^{a}\pm0,12$	$50,0^{a}$

** FWP = flour waste of pieces and FWB = flour waste of bark.*
*** The determination of total carbohydrate was performed by calculating the difference using the results of moisture, ash, crude protein, crude fat, starch and crude fiber.*
Means followed by the same letter in the same column do not differ statistically among themselves. We applied the t-test at 5% probability.
Average of three measurements ± standard deviation (δn-1)

According to the law (BRAZIL, 1995), there is no reference in regard to protein content in cassava flour. Flour waste showed significant differences (Table 2). Among the flour waste analyzed, the pieces (FRP) had the lowest protein content (0.8%) and between the hull (FRE), the largest (2.2%). The meal typically have a protein content very low, which is already expected before the composition of cassava root (ALBUQUERQUE *et al*., 1993), considered a main food supply. According CEREDA & VILPOUX (2003), quoting protein content in samples of cassava flour collected in the industries of the SP, PR and SC, they ranged from 1.12

to 1.75%, close to the values found in this work for flours. Thus, a high protein content in cassava flour is recommended, which is dependent on the variety used (CEREDA & VILPOUX, 2003).

The percentage of lipids determined in flours waste was, 0.9 and 2.0% for cuts and phloem, respectively, which differ significantly (Table 2). These results were similar to that obtained by SOCCOL et. al., (1994), for the flour residue from cassava, 1.06%. The Brazilian legislation (BRAZIL, 1995), makes no reference as to the lipids in cassava flour, and the content is related to the intrinsic characteristics of the product.

Regarding the content of this ash in the flour, there was a significant difference in the pieces with the lowest value 0.6% against 1.9% observed between the shells (Table 2). Can be noted that the amount of ash samples were within the statutory limits (maximum 2.0%) (BRAZIL, 1978). The values were determined by the intermediate RAUPP et. al. (1999) for dry cassava (1.0%). High values of ash may indicate fraud or improper processing, according to Paiva (1991), be indicative of significant levels of Ca, P, Fe and Mg.

The fiber content, the Brazilian legislation does not provide values, however, we observed a significant difference between this component of the meal residue analyzed. Flour the pieces of waste was the one with the lowest level of crude fiber (3.3%), and the highest value was the flour from the waste bark (5.7%). MATTOS & MARTINS (2000), citing the amount of fiber in different foods, have adopted the following classification: foods very high in fiber (at least 7 g fibras/100 g) and high (4.5 to 6.9 g fiber / 100 g), Moderate (2.4 to 4.4 g fibras/100 g) and low (less than 2.4 g fibras/100 g). Given this classification, the flour of cassava waste analyzed showed high levels of fiber (between shell flour) to moderate (flour pieces).

The starch content of flour calculated waste showed 40.8 and 30.6% for cuts and phloem, respectively, which differed significantly (Table 2), below the minimum recommended by the legislation (minimum 70%) (BRAZIL , 1978). This result is probably due to the greater amount of starch in the pulp of the root when compared to between shell. The starch found in flour waste although not in accordance with the law, it is important to note that these may be mixed with another type of flour, thereby obtaining a mixed flour, and thus increase the starch content of the product. Another factor that may have determined the starch content of flour waste under the law is the variety of cassava and the type of reliability analysis.

Significant differences in levels of total carbohydrates were found in the constituents of flour, 48.2% and 50.0% for the flour and between pieces of bark, respectively (Table 2). The results were similar to the 87.6% determined by Costa (2004) and RAUPP *et. al.* (1999) (90.2%), taking into account the sum of starch and crude fiber.

3.4 *Assessment of microbiological waste from cassava processing minimum*

Evaluation results for microbiological waste "in nature" before and after the sanitation and waste of flour are shown in Table 3.

Table 3. Microbiological analysis of waste "in nature and the flour of cassava waste.

Sample	**Total Coliforms (NMP. g^{-1})***	**Coliforms at 45ºC (NMP. g^{-1})**	**Molds and Yeasts (UFC. g^{-1})**	**Mesophilic Aerobic Bacteria (UFC. g^{-1})****
Waste not sanitized	$2,4x10^2$	2,3x10	$> 2,5 \times 10^5$	$> 2,5 \times 10^5$
Waste sanitized	2,3x10	< 3,0	$4,7 \times 10^2$	$6,0 \times 10^3$
Flour of waste	7,5	2,0	< 2,5x10 est.	$4,4 \times 10^3$

** Most probable number per gram.*
*** Colony forming units per gram.*

The average values of enumerations for mesophilic aerobic bacteria indicated level of contamination of the waste from the minimal processing of cassava more than 2,5 x 10^5 CFU.g^{-1} (Table 3). High scores indicate mesophilic conditions unsuitable as raw material contaminated unfavorable conditions of temperature and time during processing, and potential conditions for the development of pathogens (NETO et al., 2004). After the sanitization of waste, there was a reduction in the count of mesophilic to 6,0 x 10^3 CFU.g^{-1} (Table 3). This result indicated that the concentration of chlorine sanitation and time were efficient in reducing the level of contamination. The sanitization process showed a significant reduction in the mesophilic aerobic bacteria, constituting therefore a very important step for obtaining a product with good microbiological quality. Flour waste showed a smaller amount of mesophilic aerobic bacteria (4,4 x 10^3 CFU/g^{-1}) probably caused by the drying process.

For yeasts and molds, it was observed that the meal had obtained the number < 2,5x10 est. CFU.g^{-1} (Table 3), indicating that they are within the standards established by the Ministry of Health (BRAZIL, 1997). Thus, it was found that the steps of sanitization and drying were effective in controlling the development of these microorganisms.

The average values of enumerations for coliform bacteria, expressed as most probable number per gram (NMP.g^{-1}), showed heavy contamination of waste *in nature* with NMP.g^{-1} for total coliform equal to 2,4x10^2 and 2,3x10 for coliforms at 45ºC (Table 3). The high level of coliforms found in the waste is due to the fact that these materials come from the soil and need to, procedures for cleaning and sanitization highly effective in reducing microbial load. However, the NMP.g^{-1} for coliforms at 45 º C and the total meal was 2.0 and 7.5, respectively (Table 3). These numbers can be significantly reduced through the use of higher temperatures in the drying stage, and the use of better processing of the raw material as well as storage and transportation of waste.

4. CONCLUSIONS

Waste "in nature" and cassava flour waste produced had low levels of protein, ash and lipids, however, showed high percentage of carbohydrates (starch and crude fiber). It was found that the operations of crushing and pressing led to significant changes in total cyanide content to better product quality. The manufacturing processes of the flour of cassava waste presents effective in detoxification of cyanide total, obtaining products without risk to the population. The step of pressing, in the production of flour, can only further that removal of HCN. The steps of sanitization and drying were effective in significantly reducing the number of mesophilic aerobic bacteria, fungi, total and fecal coliforms.

5. ACKNOWLEDGMENTS

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