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Research article

VALORIZATION OF SIX NEW YELLOW COLORED CASSAVA (*MANIHOT ESCULENTA* CRANTZ) FLOURS FROM CÔTE D'IVOIRE: A WIDE POTENTIAL OF UTILIZATION THROUGH THEIR PHYSICOCHEMICAL AND BIOCHEMICAL CHARACTERISTICS

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ABSTRACT: Cassava roots are generally transformed into less perishable products, to avoid their spoilage. Cassava flour, one of these products is so widely exploited that many standards took place to regularize its utilization. Thus, different flours extracted from six yellow colored varieties of cassava were analyzed in order to valorize those with best characteristics. The whole varieties registered high calories (387.17±0.05–404.31±1.29 kcal/100 g), carbohydrates (84.30±0.42–88.93±0.53 g/100 g), starch (72.50±0.04–76.85±0.45 g/100 g) and acid (50.19±0.03–97.30±0.05 meq/100 g) amounts, but very slight moisture content (4.36±0.06–5.52±0.02 g/100 g). The PCA, HAC and ANOVA were purchased and revealed dissimilarities between the flours. Three groups G1, G2 and G3 with different components were identified. The first group G1 with only one variety (V62) registered most important amount of fat (6.93±0.03 g/100 g), ash (1.60±0.30 g/100 g) and vitamin C (1.98±0.01 mg/100 g). The group G2 (varieties V4, V23, V65 and V66) recorded the highest cyanide (1.48±0.46 mg/100 g) and reducing sugar content (2.13±0.32 g/100 g). Group G3 (V63 and V64) topped the highest moisture (5.49±0.05 g/100 g) and acidity (77.98±1.17 meq/100 g). As for the pH, it went up from 5.78±0.10 to 7.06±0.10, respectively from varieties V23 to V63.
Key words: New cassava, flour, physicochemical characterization, valorization, potential utilization.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz), contributes significantly to the economy of most tropical countries though it is transformed into various useful products [1, 2]. In rural tropical areas, its root is consumed either directly after cooking, or transformed into dry and/or wet less perishable products. In west Africa, for instance, roots are converted into flour, attieke, gari, tapioca, etc. [3, 4, 5] while in Latin America, casabe (cassava flat cake), naiboa (casabe with raw sugar and grated white cheese) and buñuelos (fried cassava dough balls with cane-juice syrup), are resulting products [6]. These kinds of use aim generally to satisfy caloric need because cassava roots are very high caloric food [1, 7]. That quality is linked to their important amount of carbohydrate correlated with their starch content [8, 9, 10]. Elsewhere and all over the world, cassava is more and more involved in several products manufacturing after it transformation in flour and starch [7, 11]. Hence, cassava flour and starch occur in food industry, mainly for pastry, gelatinized products, sausage and soup consolidation [1, 12, 13]. They are also exploited in nonfood industry and are for instance involve in textile, plastic, insecticide, detergent, glue, solvent and biofuel confection [2, 7, 11]. Some pharmaceutical industries use cassava flour and/or starch in pills and tablets preparation [1]. Due to the wide range of utilization of cassava flour and starch, several criteria of regulation take place and vary following the aim purchased [1]. Hence, the Codex-Alimentarius [14] recommend some standards concerning cassava flour moisture, cyanide, ash, etc. contents. Moreover, authors like Gontzea *et al*. [15] and Munro *et al*. [16] proposed standard for oxalic acid content in foods though it's excess might induce oxalate stone formation in urinary system [17]. Several other criteria are taken into account by consumers in general and by industrial, in particular. So materials which don't comply with criteria are excluded. Moreover, cassava and starch must present exceptional physicochemical properties to be chosen by industrial.

In the same way of the previous problematic, the present study occurred in order to identify, among seven flours extracted from different cassava varieties (one white and six yellow colored pulps), the most performing in order to valorize them by presenting their potential utilizations. So their physicochemical and biochemical characteristics were determined. Then, statistical analyses (PCA, HAC and ANOVA) were purchased on the data in order to identify varieties with best characteristics.

MATERIAL AND METHODS

The vegetal material was constituted by the flours of seven varieties of cassava roots (one white ordinary and six new yellow pulps) extracted following the process of Aryee *et al*. [4] and conserved at room temperature (25 °C) in desiccators. The roots of eleven months old were harvested from the experimental plot (Adiopodoumé, Côte d'Ivoire) of the National Center of Agronomical Research (CNRA).

Physicochemical and biochemical characteristics determination

Moisture, dry matter and ash content were determined using the AOAC [18] methods. The total cyanogens content was carried out by the method of Liebig-Denige [19] and Rachid [20] method to get oxalate content. AFNOR [21] methods leaded to the pH and total titrable acidity values. BIPEA [22] methods were used to determine fat and proteins contents. Vitamin C content was obtained with the method of Tillmanns and Hirsch [23]. Reducing and total sugars were evaluated with the methods of Bernfeld [24] and Dubois *et al*. [25], respectively. As for energy value, carbohydrate and starch contents, they were calculated by difference expression recommended by FAO [26].

Statistical analysis

All analyses were made in triplicate. The principal component analysis (PCA), the hierarchical ascendant classification (HAC) and the ANOVA were performed on data, using the XLSTAT (version 2007.6) Software. All expressed results were per 100 g of dry matter.

RESULTS

Classification of cassava varieties flours

The whole cassava flours were characterized by very weak moisture contents (4.99±0.49 g/100 g) and relatively high acidity (69.90±16.57 meq/100 g), starch (75.37±1.65 g/100 g), carbohydrate (87.73±1.64 g/100 g), energy value (392.40±5.67 kcal/100 g) and dry matter (95.30±0.38 g/100 g) (Table 1). The PCA performed on flour samples characteristics identified ten discriminant characteristics and revealed three different groups of cassava varieties in the factorial plan constituted by the axis 1 and 2 (Figure 1A and B); this plan expressed 62.43 % of the whole variability among varieties. The first group G1 (varieties V62) located in the same area (of the factorial plan) as characteristics such as fat, ash and vitamin C contents, recorded the highest values of fat, ash and vitamin C. As for the second group G2 (V4, V23, V65 and V66), it got the most important amount of cyanide (1.48±0.46 mg/100 g), reducing sugar (2.13±0.32 g/100 g) and carbohydrate (88.87±1.64 g/100 g) while the group G3, presented highest acidity (77.98±1.17 meq/100 g) and moisture (5.49±0.05 g/100 g). The HAC confirmed the previous classification and précised the characteristics of each group.

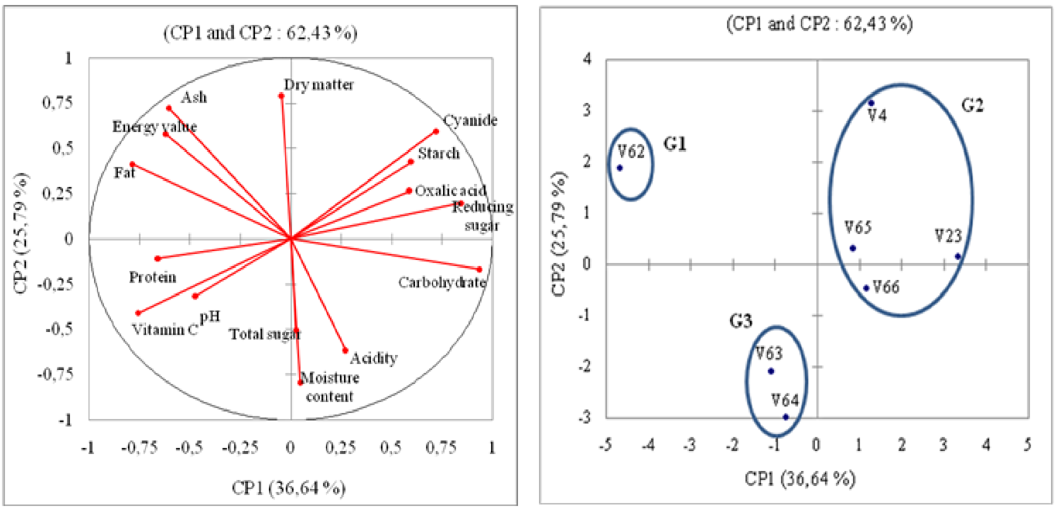
Table 1. General characteristics of cassava flours per 100 g of dry matter

Variable	Minimum	Maximum	Means	Standard deviation
Acidity (meq)	**50.19**	**97.30**	**69.87**	**16.57**
Ash (g)	1.00	1.60	1.20	0.25
Protein (mg)	1.11	2.62	2.15	0.56
Carbohydrate (g)	**84.30**	**88.93**	**87.71**	**1.63**
Starch (g)	**72.50**	**76.85**	**75.31**	**1.61**
Energy value (kcal)	**387.17**	**404.31**	**392.43**	**5.65**
Moisture content (g)	4.36	5.52	4.99	0.49
Dry matter (g)	**94.48**	**95.64**	**95.01**	**0.49**
Reducing sugar (g)	0.36	2.60	1.57	0.81
Fat (g)	3.30	6.93	3.95	1.32
Total sugar (g)	2.23	6.86	4.03	1.69
Vitamin C (mg)	0.55	1.98	1.35	0.57
Cyanide (mg)	0.53	2.13	11.19	0.58
pH	5.78	7.06	6.35	0.40
Oxalic acid (mg)	**113.52**	**250.12**	**169.05**	**52.16**

Legend: Characteristics which presented relatively high values are **in bold**.

Dissimilarity among the whole varieties of cassava flours

When taking into account the whole characteristics (fifteen), the Fisher test of the ANOVA revealed a significant difference from a variety to another (Tables 2a and 2b). Indeed, the pH ranged from 5.78±0.02 (V23) to 7.06±0.03 (V63) when the reducing and total sugars amount increased from 0.36±0.03 to 2.60±0.01 g/100 g and from 2.23±0.03 to 6.86±0.04 g/100 g, respectively. Above all, variety V62 registered very important amounts of fat (6.93±0.03 g/100 g), ash (1.60±0.30 g/100 g), calories (404.31±1.29 kcal/100 g), proteins (2.40±0.10 mg/100 g) and vitamin C (1.98±0.01 mg/100 g). Varieties V4, as for it, topped the highest starch (76.85±0.45 g/100 g), cyanide (2.13±0.03 mg/100 g), but the weakest vitamin C contents (0.55±0.02 mg/100 g). The highest acidity value were recorded by varieties V63 (97.30±0.05 meq/100 g); V65 (83.94±0.03 meq/100 g) and V66 (75.65±0.08 meq/100 g), also presented high acidity. As for variety V64, it presented the most interesting amount of proteins (2.62±0.02 mg/100 g), but the slightest starch content (72.50±0.04 g/100 g).



A B

Fig. 1 Projection of different physicochemical parameters (A) and cassava flours (B) in the factorial plan (CP1 and CP2)

Table 2a. Physicochemical characteristics of cassava flours.

Varieties	Moisture (g)	Dry matter (g)	Ash (g)	pH	Acidity (meq)	Cyanide (mg)	Oxalic acid (mg)
V4	4.36±0.06d	**95.64±0.04a**	1.50±0.04ab	6.50±0.30b	50.19±0.03g	**2.13±0.03a**	220.58±0.30b
V23	5.47±0.52ab	94.53±0.01ef	1.01±0.01c	5.78±0.02e	64.74±0.04d	1.61±0.05b	**250.12±0.12a**
V62	4.77±0.04c	95.23±0.04c	**1.60±0.30a**	6.32±0.02c	58.77±0.05e	0.53±0.04e	124.70±0.30f
V63	5.45±0.05ab	94.55±0.04e	1.20±0.20bc	**7.06±0.03a**	**97.30±0.05a**	0.86±0.07c	190.10±0.30c
V64	**5.52±0.02a**	94.48±0.02f	1.01±0.01c	6.50±0.05b	58.65±0.04f	0.53±0.04e	133.40±0.40e
V65	4.47±0.07d	95.53±0.01b	1.10±0.10c	6.10±0.03d	83.94±0.03b	1.07±0.02c	150.90±0.20d
V66	4.87±0.06bc	95.13±0.04d	1.00±0.10c	6.17±0.03d	75.65±0.08c	1.07±0.02c	113.52±0.03g

Legend: Values with deviations are expressed per 100 g of dry matter. The highest are i**n bold** and the weakest are underlined.

Table 2b. Biochemical characteristics of cassava flours

Varieties	Reducing sugar (g)	Total sugar (g)	Starch (g)	Carbohydrate (g)	Energy value (kcal)	Fat (g)	Proteins (mg)	Vitamin C (mg)
V4	1.82±0.05d	2.78±0.06e	**76.85±0.45a**	88.17±0.44b	391.11±2.47bc	3.45±0.05b	2.52±0.02a	0.55±0.02e
V23	**2.60±0.01a**	3.61±0.03d	**76.73±0.03a**	88.87±0.03a	390.82±4.25bcd	3.54±0.50b	1.11±0.01c	0.90±0.10d
V62	0.64±0.01f	2.23±0.03g	73.86±0.35d	84.30±0.42d	**404.31±1.29a**	**6.93±0.03a**	2.40±0.10a	**1.98±0.01a**
V63	0.36±0.03g	2.64±0.02f	76.33±0.33ab	87.45±0.35c	387.17±0.05d	3.30±0.20b	2.60±0.10a	**1.97±0.02a**
V64	1.48±0.08e	**6.86±0.04a**	72.50±0.04e	87.41±0.06c	388.23±0.43cd	3.44±0.04b	2.62±0.02a	1.55±0.05c
V65	2.19±0.07b	4.84±0.05cb	75.68±0.48bc	88.93±0.53a	393.16±3.58b	3.50±0.40b	2.00±0.55ab	1.64±0.03b
V66	1.91±0.04c	5.27±0.02b	75.20±0.57c	88.83±0.61ab	392.21±1.59bc	3.50±0.50b	1.80±0.06bc	0.88±0.05d

Legend: Values with deviations are expressed per 100 g of dry matter. The highest are i**n bold** and the weakest are underlined.

DISCUSSION

The whole flours of the present study contained cyanide and oxalic acid in various amounts, whereas these substances represent anti-nutritional factors. Indeed, the excess of cyanide would lead to diseases such as endemic goiter, tropical ataxic neuropathy [27] and epidemic spastic paraparesis [28]. The oxalic acid excess might increase oxalate stone formation in urinary system [17]. Hence, regulator standards are recommended by the Codex-Alimentarius [14] Codex for the cyanide content (< 1 mg/100 g of dry matter) and by Gontzea *et al.* [15] (< 500 mg of oxalic acid/100 g of dry matter). The whole cassava varieties flours complied with both standards except for varieties V4 and V23 which were not conform to the Codex-Alimentarius standard. Thus their uses might be limited either to animal feeding because of their high energy values or to nonfood industries purposes They could, for instance occur in starch, dextrin, plastic, textile, glue, alcohol, glucose and biofuel manufacturing because of their interesting amount of starch, reducing and total sugars.

Let's recall that above all, varieties V4 and V23 registered several interesting properties, as the other varieties did. In fact, the whole flours registered very slight moisture content which might be linked to the efficiency of the process. That situation might certainly increase flours shelf life [29]. It is worth noting that the Codex–Alimentarius [14] recommended moisture content less than 13 % for cassava flours, now, the present samples presented a maximum of 5.52 %. So they complied not only with the Codex-Alimentarius standard but also with the recommendation of Bencini and Waltson [30] (< 6 %) to definite flours quality. Hence, the whole flours might be qualified as *very good* flours with high potential of long conservation. Moreover, their relatively high acidity which would inhibit microorganism's development [31, 32] would consolidate their safety. The acidity linked to the presence of organic acids (acetic, lactic, butyric, etc) would also constitute an advantage for the edible flours (V62, V63, V64, V65 and V66). Indeed, organic acids would not only provide sourness to meal, as many consumers need [33] but might also reduce infant diarrhea [34]. Moreover, due to their rich content in sugars (reducing and total) the flours would also provide a natural sweet taste to meals mainly as varieties V64, V65 and V66 are concerned.

These edible cassava varieties flours could be consumed in households or be exploited in food industries. Hence varieties V62, V63 and V64 could be integrated in composite flours for infant weaning as proposed by Trèche *et al*. [35] (*vitafort*) and Zannou *et al*. [36] (*FAS* and *FMS*). This integration would be more advantageous though these flours contained interesting amount of proteins, vitamin C and fat. Moreover, according to Safo-Kantanka *et al*. [37], they would constitute high sources of vitamin A linked to their native content in β-carotene. It is important precising here that the amounts of protein, vitamin C and fat, in the whole flours, were higher than those reported by many authors such as Apea-Bah *et al*. [38]; Maziya-Dixon *et al*. [39]; Ogunjobi and Ogunwolu [40] and Olatidoye and Sobowalé [41], about cassava flour. However, it would be necessary adding some over source of proteins and vitamins (fish, meat, milk, etc.), in order to reach daily amount of nutriments and prevent infants from malnutrition.

Concerning their use in food industries, owing to their relatively high pH which complied with those obtained by Ingram [42], varieties V62, V63, V64, V65 and V66 could easily be mixed all together and occur in composite flours for pastry as proposed by Oluwamukomi *et al*. [43] in biscuit manufacturing, and by Eggleston *et al*. [12] for bread confection. In fact, these pH might suggest the starch safety (absence of breakage) [4, 38] which is recommended in pastry. Moreover, their interesting sugar contents would confer crispy texture to bread and biscuits, due to Maillard's reaction [44] between reducing sugar and amino acid [45]. The whole edible flours could also be used as raw material in gelatinized products (flakes and frosts), and as texturant in soup and sausage as proposed by Wilfred-Ruban *et al*. [13].

Of course, all the flours might provide to producing countries, via farmers and traders an exceptional source of prosperity thank to their wide possibility of use.

CONCLUSION

The whole varieties of the present study presented very high energy values, which confirmed their quality of caloric food involved in the food security program of the FAO. Varieties V4 and V23 uses might be limited to animal feeding and nonfood industry because their cyanide content exceeded the Codex standard. The others varieties V62, V63, V64, V65 and V66 could occur in a wide range of purposes (food and nonfood). They could be either consumed in households, or be exploited in food industries for pastry because of their interesting pH. Moreover, their sugars might confer crispness to bread and biscuits. They could also be involved in gelatinized products, soup and sausages.

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