Journal of Food and Nutrition Sciences
2025, Vol. 13, No. 5, pp. 282-288
https://doi.org/10.11648/j.jfns.20251305.17

Research Article

Production, Nutritional and Sensory Characterization of Gluten-Free Pasta Based on Local Products: Plantain Banana, Cassava, Soybean and Cashew Apple

Koumbou Hien[1,*], Gninfanni Silvère Ouattara[2,3], Doudjo Soro[1], Kouadio Ernest Koffi[3]

[1]UMRI 58: Chemical, Food, and Environmental Process Engineering, Felix Houphouet-Boigny National Polytechnic Institute, Yamoussoukro, Côte d'Ivoire

[2]Department of Biochemistry and Genetics, Peleforo Gon Coulibaly University, Korhogo, Côte d'Ivoire

[3]Biosciences Training and Research Unit, Felix Houphouet-Boigny University, Abidjan, Côte d'Ivoire

Abstract

The aim of this project was to promote our local products in the production of gluten-free pasta. The local products used were plantains, cassava, soybeans, and cashew apple bagasse. To achieve this objective, the pasta was produced after several unit operations using a composite flour made from plantain, cassava, soybean, and cashew apple bagasse flours. The composite flour and the pasta produced were subjected to laboratory analysis. Next, a comparative study of the physical, chemical, and biochemical characteristics of the pasta produced and the composite flour used to produce it was carried out. Since this pasta will be consumed by humans, a sensory analysis was conducted to evaluate human appreciation of the pasta. Physicochemical and biochemical analyses revealed that the composite flour obtained has a protein content of 16.94%, a fiber content of 7%, and an energy value of 404.6 kcal/100g. After being processed into pasta, the final product has a protein content of 15.52%, a fat content of 11.50%, and an energy value of 393.58 kcal/100g. In terms of sensory characteristics, the results of the hedonic test showed that the majority of panelists (52.9%) found the pasta satisfactory. However, the dark color of the pasta was rejected by a minority of panelists. These results demonstrate the potential of this composite flour in the formulation of gluten-free pasta.

Keywords

Pasta, Composite Flour, Nutritional Value, Sensory Analysis

1. Introduction

Plantain banana is an important source of food and income for all rural populations in the humid tropics of Africa [1].

Plantain banana is the leading food crop in Ivory Coast forest zone, with production estimated at 1,600,000 t/year and national consumption estimated at around 800,000 t/year. This significant difference is explained by post-harvest losses and the lack of conservation techniques [2].

Plantain has a variety of uses: the most popular dishes are

*Corresponding author: koumbou.hien@giz.de (Koumbou Hien)

Received: 31 July 2025; **Accepted:** 13 August 2025; **Published:** 30 October 2025

foutou, alloco and foufou. It can also be eaten braised, as chips, in stews, etc. On the industrial front, plantain can be processed into flour, which can be used to make bread, doughnuts, pasta, cookies and cakes, or in the formulation of baby foods. This flour can also be used to make foutou and foufou. However, no Ivorian industrial operator has yet developed this product [2].

Pasta is a staple food in many countries. They are an essential source of carbohydrates in daily diets throughout the world [3]. However, the rise in gluten intolerance and allergy has prompted scientific research into the development of gluten-free alternatives. With this in mind, the use of composite flours, obtained from different gluten-free plant sources, is emerging as a relevant solution for diversifying the product offering, while meeting consumers' nutritional and taste needs.

Plantain, cassava, soy and cashew apple flour are locally available, nutrient-rich ingredients. Each of these ingredients has specific nutritional properties: plantain and cassava are rich in carbohydrates, soy in protein and cashew in polyphenols and fiber. Combining these ingredients in a composite flour could offer products enriched with essential nutrients, while maintaining acceptable texture and sensory characteristics for consumers [4, 5].

Gluten-free pasta often faces sensory and structural challenges, particularly in terms of texture and taste, as gluten plays an important role in the elasticity and cohesion of conventional pasta [6]. In the absence of gluten, achieving a pleasant texture, close to that of conventional pasta, becomes a challenge.

In addition, the nutritional composition of many gluten-free pastas available on the market often remains deficient in certain essential nutrients, particularly protein and fiber [7].

The development of pasta based on composite flour (plantain, cassava, soy and cashew apple) could address both these issues, while enhancing the use of local ingredients in developing countries.

The aim of this study is to develop and characterize gluten-free pasta based on a composite flour of plantain, cassava, soy and cashew apple.

2. Materials and Methods

2.1. Biological Materials

The raw material used is a composite flour made from plantain flour, soy flour, cassava and cashew apple.

1) The plantain fruits used for flour production are the Affoto cultivar (false horn), fully ripe at green ripening stages (1 and 2).
2) The unfermented cassava roots used to produce our flour are sweet varieties.
3) Soya beans of white varieties.
4) Cashew apple cakes from pressing during juice production.

Thanks to an experimental design already carried out, the proportions of the different flours used are as follows:

1) Plantain flour: 55%;
2) Cassava flour: 10%;
3) Soya flour: 20%;
4) Cashew apple flour: 15%;

2.2. Methods

2.2.1. Pasta Production

Pasta is probably the most natural of all food products, and this is due to its ingredients and production methods (figure 1). The basic ingredients are durum wheat semolina or soft wheat flour and water.

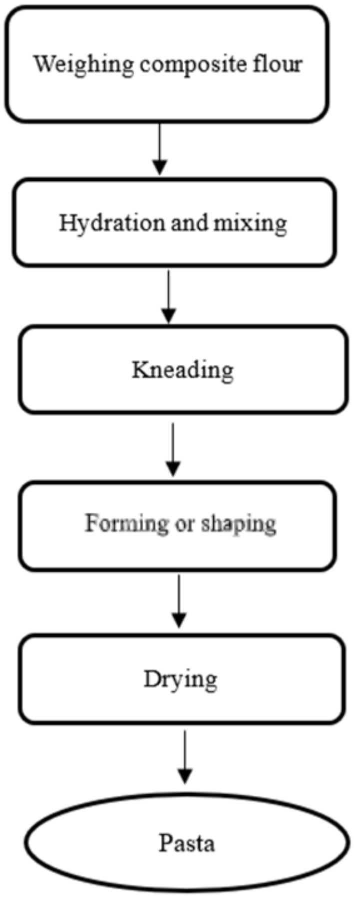

Figure 1. *Pasta production diagram.*

For our study, the pasta was produced from the optimum composite flour formulation based on plantain banana/manioc/soy/cashew flour.

The pastification process consists in hydrating, kneading, extruding and drying the resulting pasta. The result is a product with a compact final structure made up of a protein network enclosing starch granules.

Pastes are extruded at pressures of 80 and 140 bar, which also causes them to heat up [8].

The extrusion temperature should not exceed 40 ℃, as at this temperature the protein structure will be too compact, and above 40 ℃ there is a risk of starch gelatinization. For this reason, the die is cooled by circulating cold water [9].

After hydration and kneading of the composite flour, the resulting mixture was gradually introduced into the extruder funnel (China brand). This process uses an Archimedean screw to push the mixture through an extrusion throat. After extrusion, the resulting pastes are dried in an electric rack dryer at 70 ℃ for 4 hours.

2.2.2. Physicochemical Characterization of Composite Flour and Pasta Products

1) Moisture Content

Moisture content is determined using a moisture meter. A quantity of 5g of the compound flour is weighed into a scoop. The measurement is made by drying the sample until all moisture is completely removed. The result is read off directly as a percentage.

2) Fiber Content

The crude fiber content of samples is determined using the [10] method. A double hot acid (200 ml sulfuric acid 0.225 N) and alkaline (200 ml sodium hydroxide 0.3 N) hydrolysis destroying proteins and digestible carbohydrates contained in 3 g of sample was carried out, then the hydrolysate was defatted with acetone. The residue was dried and weighed. After calcination, the ash weight was subtracted [11].

3) Ash Content

Ash was determined using the [10] method. Mineral matter or ash is the residue obtained after destruction of the organic substance by calcination.

The sample was introduced into a muffle furnace at 600 ℃ for 4 hours and cooled in a desiccator.

4) Protein Content

The method used is that of Kjeldahl [12]. This method comprises two main stages: sulfuric mineralization or digestion, and distillation followed by assay.

5) Lipid Content

The fat content of the dough was extracted using the [13] soxhlet method. The extraction yield corresponds to the fat content per 100 g of dough.

6) Carbohydrate Content and Energy Value

Total carbohydrates and energy value were determined using the calculation method recommended by the [14]. This method takes into account moisture, fat, protein and ash content. Calculating the energy value of a food is based on quantifying the macronutrients it contains: carbohydrates, lipids and proteins. After obtaining the proportion of these different nutrients, each nutrient is multiplied by its calorific energy value.

2.2.3. Culinary Quality of Pasta

1) Optimum Cooking Time (OCT)

Minimum, optimum and maximum cooking times correspond respectively to the time required for starch gelatinization, the time required to give the dough the desired texture, and the time beyond which the products disintegrate in the cooking water [15].

A 100g sample of pasta was immersed in 250 mL of boiling water. After every 2 minutes, a portion of pasta was taken and touched to check its cooking quality.

2) Swelling Index (Cooking Weight)

Swelling is the weight gain of pasta during cooking, reflecting the amount of water absorbed. It is an indicator of pasta's water absorption capacity [16].

To measure it, the difference in pasta weight before and after cooking was assessed. Sample preparation followed the same procedure as that used to determine the optimum cooking time.

2.2.4. Organoleptic Evaluation

The sensory analysis consisted of a hedonic test to measure the acceptability or rejection of the pasta products consumed by the panelists.

The untrained panel was made up of 65 neutral people, male and female, selected on the basis of their availability and motivation to take part in the sensory test.

Tasters were asked to rate the coded sample of the product, indicating their degree of appreciation on a 9-level scale. To do this, they indicate a category on a scale ranging from “like a lot” to “don't like at all”.

Each panel member is asked to give a score from 1 to 9 for all the organoleptic characteristics indicated on the tasting sheet, based on their assessment. Subjects are seated at their tasting stations, with some distance between them to avoid contact. The sample is presented to each taster on a plastic plate, and they can taste it as many times as they like to ensure their score.

2.2.5. Statistical Analysis of Results

The statistical analysis of the results obtained during the study and the graphs were produced using Excel software version 2024. The values presented are the means of three determinations ± standard deviations.

3. Results and Discussion

The results of the physico-chemical and biochemical analyses are summarized in the table below (table 1).

***Table 1**. Physico-chemical and nutritional composition of composite flour and pasta products.*

Parameters	Composite flour	Pasta
Moisture content (%)	9.48 ± 0.36	10.24 ± 0.16
Ash content (%)	3.95 ± 0.13	2.79 ± 0.002

Parameters	Composite flour	Pasta
Protein content	16.94 ±0.04	15.52 ±0.04
Lipid content (%)	11.50 ±0.14	6.74 ±0.07
Carbohydrate content (%)	59.13 ±0.27	67.70 ±0.4
Fiber content (%)	7 ±0.13	1.51 ±0.05
Energy value (Kcal)	404.6 ±2.49	393.58±2.1

Moisture content quantifies the amount of water in a product or ingredient, which can promote microbial growth or, through migration, alter the quality of other ingredients. The flour's average moisture content of 9.48% ensures that it keeps well. This result is similar to that obtained by [17] for complex flour formulations based on wheat, cashew kernels and plantain banana (9.02% - 11.41%). On the other hand, it is higher than the results obtained in the work of [18], which concerned the formulation of a composite flour based on plantain and cashew kernels (3.06% - 6.43%).

According to the results of this study, the average moisture content of the pasta was 10.24%. This is within the range recommended by [19] (12.5%) and [20] (9.48% - 10.24%). This moisture level is low enough to minimize the risk of microbial growth, contributing to good product stability, and high enough to guarantee a pleasant texture in the mouth.

The ash content of a food or ingredient corresponds to the quantity of inorganic matter remaining after complete combustion of the organic matter. This inorganic matter is mainly composed of minerals. The average ash content of the optimum flour from the formulation study is 3.95%. This is similar to the work of [21] in enriching couscous with soy. The average ash content of gluten-free pasta (2.79%) is significantly higher than that of wheat-based pasta (0.5 to 1% according to [19]). This high level is mainly attributed to the presence of ingredients naturally rich in minerals, such as soy and cashew apples, known for their calcium, potassium, magnesium and iron content [22]. This increased content is beneficial for those following a gluten-free diet, often seeking to make up for mineral intakes absent in conventional gluten-free products.

In this study, the lipid content of pasta was determined to be 6.74%, which slightly exceeds the range (4-6%) obtained by [23] during their work on legume-based gluten-free pasta.

These levels are probably high due to ingredients such as soy and cashew that are naturally rich in fat, adding flavor and creaminess to the final product.

Fiber regulates intestinal transit, captures a portion of lipids and carbohydrates and may also reduce the risk of obesity and metabolic diseases [24]. The average fiber content of the compound flour is 7%, which is higher than that obtained by [24] (2.01% - 2.83%) in the formulation of compound infant flours in Cameroon. This fiber content can be explained by the presence of cashew apple in the blend, as cashew apple cakes are rich in cellulose and hemicellulose, the main components of fiber [25].

As for the average fiber content of 1.51% obtained in the pastes submitted to the study; this is lower than the values reported by [23], which is 2.5 to 4% for similar products. This low fiber content could be due to processing (e.g. extrusion), which reduces the fiber content in finished products. This result suggests that to improve the nutritional value of the gluten-free pasta studied, it might be beneficial to enrich the formulation with additional fiber.

The carbohydrate content obtained in the composite flour is 59.13%. This result is lower than that of [17] (69.04% - 73.30%) in the formulation of composite flour based on wheat, cashew kernel and plantain. Compared with the results of [22] with a rate between 60-65%, the doughs submitted for study are slightly richer in carbohydrates (67.70%).

These different rates can be explained by the presence of cassava, soy and plantain, sources of complex carbohydrates, which also provide a pleasant texture and a better feeling of satiety.

The energy value of the composite flour obtained (404.6 kcal) falls within the range reported by [22] (350 and 420 kcal), confirming that the combination of protein and lipid ingredients, such as soy and cashew apple, contributes significantly to the flour's energy density.

The energy value determined in pasta made with composite flours is in line with that of [22] (around 380-400 kcal per 100 g), validating the energy value of this type of gluten-free product enriched with legumes and nuts.

The results of appreciability tests on gluten-free pasta are shown in the figures below (figure 2 and figure 3).

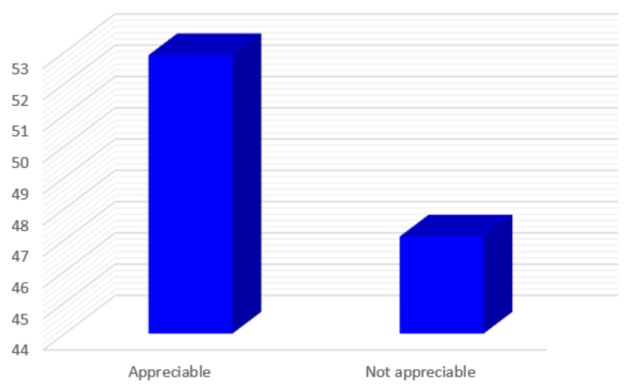

Figure 2. *Appreciability of gluten-free pasta.*

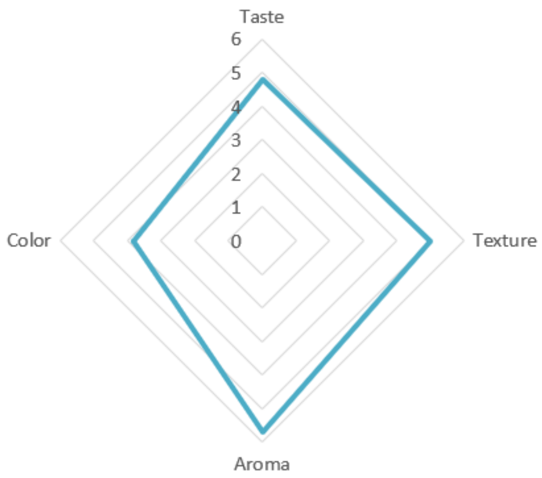

Figure 3. *Assessment of pasta parameters.*

The overall assessment of taste, aroma, appearance and texture is shown in (Figure 3). The assessment of pasta by a panel of untrained people is shown in (Figure 2).

On a scale from 1 to 9, texture and aroma stand out, with an average of 5.0 and 5.7 respectively. Taste also scored well, with an average score of 4.8, while color was the weakest element, with an average score of 3.8.

As far as the hedonic analysis is concerned, the majority of panellists (52.9%) found pasta products satisfactory. This satisfaction could be explained by taste, texture and aroma. This indicates good acceptance of the taste profile by this large group of panelists. The composite flour used, composed of plantain, manioc, soy and cashew apple, seems to produce a pleasant taste, despite the absence of gluten. Gluten, on the other hand, is often central to the familiar taste of conventional doughs. Indeed, gluten plays an important role in the texture of pasta, contributing to elasticity and bakeability. The fact that these pastas achieved such a high acceptability score indicates that the combination of plantain, cassava, soy and cashew apple flour offers another way of adding value to our local products. However, 47.1% found the pasta unsatisfactory. This could be explained by the dark color. Indeed, color is an essential visual criterion that influences the overall perception of the product, especially for pasta products where appearance can play an important role in the purchasing decision. The combination of ingredients such as plantain and soy can give a different hue to composite pasta, which could explain the refusal.

In a cooking test, we obtained a cooking time of 8 minutes and a swelling index of 120.08 (Table 2).

Table 2. *Culinary quality of pasta products.*

Parameters	Optimum time	Swelling index
Values obtained	8 min	120.08%

An Optimal cooking time of 8 min indicates that the pasta is sufficiently hydrated and gelatinized without disintegrating, which is a good indicator of quality for a gluten-free flour formulation. In their study of gluten-free pasta based on cassava and plantain, [20] reported a cooking time of between 7 and 9 minutes, similar to the results of this study. This result shows that the composite flour of plantain, cassava, soy and cashew confers satisfactory baking properties to pasta, comparable to commercial gluten-free products.

The swelling index of 120.08% means that pasta increases its weight by around 1.2 times after cooking, reflecting its ability to absorb water without disintegrating. This index is generally taken into account when judging the texture and consistency of cooked pasta. A good swelling index is important if pasta is to be pleasant to chew, without being too sticky or too soft. Research by [22] on legume-based gluten-free pasta indicated swelling indices between 110 and 130%. The results of this study are therefore in the middle of this range, suggesting good textural quality. In fact, moderate swelling, such as 120.08%, is generally perceived positively, as it guarantees a pleasant texture without excess stickiness.

4. Conclusion

The production of gluten-free pasta based on plantain, cassava, soybean and cashew apple composite flour clearly induces a considerable increase in the nutritional composition of composite flours, notably in protein, lipids, ash, fiber and energy, as well as high acceptability.

The use of these local flours will not only increase the added value of these local resources, but also combat cases of illness linked to gluten intolerance.

These pasta products could be recommended to all segments of the population, especially those suffering from gluten intolerance.

Abbreviations

AOAC	Assoiciation of Official Analytical Chemists
FAO	Food and Agriculture Organization
MIN	Minute
OCT	Optimum Cooking Time

Acknowledgments

The authors thank the technical staff of the Laboratory for their assistance.

Author Contributions

Koumbou Hien: Conceptualization, Writing – original draft, Resources, Writing – review & editing

Gninfanni Silvère Ouattara: Writing – review & editing, Validation

Doudjo Soro: Writing – review & editing, Supervision, Validation, Visualization

Kouadio Ernest Koffi: Writing – review & editing, Supervision, Validation, Visualization

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] KOUADIO KOUAKOU, K. A., COULIBALY, S., ATCHIBR, L. O, KOUAME, G., and MEITE, A., 2012. Comparative nutritional evaluation of the fruits of three banana hybrids (CRBP 39, FHIA 17 and FHIA 21) with those of the Orishele variety. TROPICULTURA, 30(1), 49-54.

[2] Perrin, A., Ricau, P. and Rabany de Rongead C., 2015. "Etude de la filière Banane Plantain en Côte d'Ivoire. Projet «Promotion et commercialisation de la Banane Plantain et du Manioc en Côte d'Ivoire»". Financement: Comité Français pour la Solidarité Internationale (CFSI); 2015. https://www.alimenterre.org/system/files/ressources/pdf/1067-diagnostic-de-la_filiere-banane-plantain-cotedivoire.pdf

[3] Wagner, M., Valle G. D., Abecassis, J., Buleon A., Lourdin, D., M. H. Morel, M. H., Cuq B., 2009. Determination of rheological properties of pasta during cooking. AEMIC Technical Days. (60th Technical Days of the Cereal Industries), Reims, France. 1 p.

[4] N'guyen, T. H., Tran, M. Q., LE, V. P. and PHAM, T. A., 2019. Study on the use of composite flours from local plant sources for the development of gluten-free products. Journal of Food Science and Technology, 56(7), 12-19.

[5] Boukour, R., Belkacemi, K., Djoudi, F. and AÏT KAKI, F., 2020. Nutritional and sensory properties of composite flours: an alternative for fortified food products. Food Research International, 48(3), 98-105.

[6] Gallagher, E., Gormley, T. R. and Arendt, E. K., 2004. Challenges in the development of gluten-free bakery and pasta products. Cereal Chemistry, 81(1), 3–14.

[7] Schmidt, J. A., Graff, S., Balet, S. and Bosset, J. O., 2016. Nutritional and sensory evaluation of gluten-free pasta products. Journal of Food Composition and Analysis, 45(5), 27–33.

[8] Petitot, M., Brossard, C., Barron, C., Larre, C., Morel, M.-H., and Micard, V., 2009. Modification of pasta structure induced by high drying temperatures. Effects on the in vitro digestibility of protein and starch fractions and the potential allergenicity of protein hydrolysates." Food chemistry, 116(2), 401-412.

[9] BOUDREAU A. and MENARD G., 1992. Le blé éléments fondamentaux et transformation. Presses de l'université Laval. Pp. 196 - 201.

[10] AOAC, 1990. Association of Official Analytical Chemists, Official Methods of Analysis". 15th edition, Washington D. C. USA.

[11] Diallo, S. K., SORO, D., KONE, Y. K., ASSIDJO, N. E., YAO, B. K. and Dago, G., 2015. Fortification and substitution of wheat flour by Voandzou flour (Vigna subterranea L. verdc) in the production of bakery products," International Journal of Innovation and Scientific Research, 18(2), 434-443.

[12] BIPEA (1976). Interprofessional Bureau of Analytical Studies, in Collection of methods of analysis of European communities, BIPEA, Gennevilliers, pp 51-52.

[13] AFNOR, 1991. French Association for Standardization, Catalogue, ed. Paris Afnor, 783p.

[14] FAO, 2002. Food energy-methods of analysis and conversion factors. FAO Ed, Rome, 97 p.

[15] ABECASSIS J., 2011. Innovations to improve the quality of cereal production and products. Joint Research Unit IATE Agropolymer Engineering and Emerging Technologies INRA, CIRAD, SUPAGRO, UM II Montpellier, France. pp. 9-14.

[16] Marti, A., Caramanico, R., Bottega, G. and Pagani A., 2013. Cooking behavior of rice pasta: Effect of thermal treatments and extrusion conditions. Food Science and Technology, 54, 229-235.

[17] BADJE D. S., Soro, D., Niamketchi, G. L. and Koffi, K. E., 2019. Study of the chemical, functional and rheological behaviors of mixtures of wheat flour (Triticum aestivum), cashew kernel (*Anacardium occidentale L*) and plantain banana (*Musa paradisiaca*). Afrique Science, 15(6), 143-155.

[18] Fofana, I., Soro, D., Yeo, M. A., and KOFFI, K. E., 2017. Influence of Fermentation on the Physicochemical and Sensory Characteristics of Composite Flour Based on Plantain Banana and Cashew Almond. European Scientific Journal, 13(30), 395-416.

[19] FAO (2003). Technical Manual on Gluten-Free Products. FAO Ed, Rome, 97 p.

[20] Sanni, L. O., Adebowale, A. A., Filani, T. A., Oyewole, O. B., and Westby, A., 2006. Characterization of cassava and plantain flours for gluten-free products. Journal of Food, Agriculture & Environment, 4(3&4), 74-78.

[21] Hama-Ba, F, Silga, R. P. and Diawara B., 2016. Evaluation de la qualité et de l'acceptabilité de couscous à base de trois formulations de farines composites enrichies au soja (Glycine max) et au moringa (*Moringa oleifera*). International Journal of Biological and Chemical Sciences, 10(6), 2497-2510.

[22] Adebowale, A., Adegoke, M., Sanni, S., Adegunwa, M. and Fatuga, G. (2012) Functional Properties and Biscuit Making Potentials of Sorghum-Wheat Flour Composite. America Journal Technology, 7, 372-379. https://doi.org/10.3923/ajft.2012.372.379

[23] Meyer, K. A., Kushi, L. H., Jacobs, D. R., Slavin,., J., Sellers, T. A., et Folsom, A. R. (2000). Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. Acta Virologica, 19(6), 500.

[24] Ponka, R., Nankap, T. E., Tambe, T. S., and Fokou. E., 2016. Nutritional composition of some artisanal infant flours from Cameroon. International Journal of Innovation and Applied Studies, 16(2), 280-292.

[25] Soro, D., 2008. Concentration by tangential microfiltration and characterization of cashew apple carotenoid extracts. Institute of Hot Regions. Master of Naval Research, Montpellier, SupAgro, 67 p.