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Research Article

Nutritional, antinutritional, and sensorial properties of *Manihot esculenta* cassava sticks from five varieties as affected by *Arbuscular mycorrhizal* fungi in field conditions

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Abstract

Cassava is a mycotrophic and staple crop implicated in the diet of tropical environment populations. This work evaluates the influence of cassava varieties and *Arbuscular mycorrhizal* (AM) fungi inoculation on the nutritional, antinutritional, and sensorial properties of cassava sticks. Cassava root varieties were peeled, cleaned, and cut into pieces before being soaked for 72 hours. The resulting paste was grounded and molded to form sticks 40 cm long, and then boiled at 100°C for 25 minutes. Cooked, sticks were subjected to sensory analysis using color, texture, aroma, taste, and general acceptability as attributes. Nutritional and antinutritional properties were analyzed using standard methodology. Results indicate a large variation in the sensorial quality of cassava sticks, with respect to varieties and the AM fungi status of cassava plants. Sticks from mycorrhized AE, I090590, and TME/693 varieties showed the best score for all attributes, indicating their best appreciation. None AM fungi 01/1797, I090590 cassava sticks showed fewer scores indicating their less appreciation. Sticks from AM fungi cassava plants showed better sugars, proteins, lipids, ash, fibre, Fe, P, Ca, Mg, K, and energy values compare to those from none AM fungi cassava varieties. Significant reduction of all the antinutrients tested was recorded for sticks from AM fungi cassava varieties, with the best 62.7% attributed to cyanide content for TME/693 variety. TME/693 is the best cassava variety for the production of sticks. Production of cassava must be done with AM fungi to ensure the best yield and quality of the derived products.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a tuberous root plant of the Euphorbiaceae family, grown in tropical zones with great contribution to food security for people in this area. Implicated in the diet of around 800 million people, cassava is increasingly popular and is becoming a staple food in many countries, especially in the humid tropics [1]. Cassava plants are of great contribution to the nutrition of populations and are implicated in the development of industrial purposes. Cassava and plantain account for the best source of starch in the diet of Cameroonian populations [2]. Their tubers and leaves are rich sources of carbohydrates, proteins, vitamins, and minerals. Tuber by-products of cassava have protein content ranging from 14-40%, minerals, vitamins B1, B2, C, and carotenes [3]. Cassava tubers have a short shelf-life of only 1–2 days after harvest, raising the problem of transformation into by-products [4]. Cassava is highly consumed in the form of cooked tubers and most of the time used to produce by-products such as "water fufu", "fufu", cassava sticks, gari, and cassava beer [5]. Cassava sticks are one of the derivatives of cassava tubers whose processing technology is cheaper and easier because it requires less energy consumption and appreciates yields [6-7]. Depending on the varieties, cassava can be a source of non-nutritive compounds, with various rates of toxicity, which can interfere with the digestibility and absorption of useful nutrients by consumers of the cassava base diet. Cyanide is the most toxic and dangerous antinutrient found in cassava tubers, which limits its consumption [8-9]. Several health disorders and diseases related to cyanides have been reported in populations consuming cassava tubers, ranging from tropical neuropathy to glucose intolerance, goiter, and cretinism [10-11]. They also include phytates, oxalates, saponins, and tannins, a group of compounds that affect the bioavailability of minerals, notably calcium, and magnesium, by inhibiting the digestive enzymes responsible for protein breakdown in the gut of cassava and cassava derivatives consumers. They are generally credited with a bitter taste but have some health benefits for consumers [12-13]. Strategies to manage non-nutritive compounds in cassava involve processing methods for the formulation of derivatives, and traditional breeding leading to cassava cultivars with varying levels of non-nutritive elements [14]. In all ecosystems, rhizosphere organisms contribute in several ways to plant growth and productivity. Plant growth under symbiosis of AM fungi usually shows a high amount of mineral elements such as immobile phosphate ions, and micronutrients including nitrogen, potassium, magnesium, and iron [15]. AM fungi form symbioses with about 80% of vascular plant species in all terrestrial biomes, with great ecological importance, mainly in enhancing plant productivity [16-17]. Environmental factors, including microorganisms present in the plant rhizosphere, can modulate the rate of biosynthesis of primary and secondary metabolites. The symbiotic relationship between AM fungi and cassava affects the metabolism of the plant, resulting in high biomass production [18]. With repercussions on the nutritional quality of cassava and its by-product [19-14]. The inoculation of AM fungi on cassava plants has shown changes in their physiology with a significant increase in yield [20-21], and changes in the content of carotenoids and volatile components [19-22]. AM fungi can also enhance the biosynthesis of valuable phytochemicals in edible plants and make them suitable for a healthier food production chain [23-24]. The bioaccumulation of primary and secondary metabolites by AM fungi is clearly determined, but few studies address the impact of these fungi on the sensory, nutritional, and anti-nutritional value of products derived from several cassava varieties still not common. This work evaluates the influence of cassava varieties and AM fungi inoculation on the nutritional, antinutritional, and sensorial properties of cassava sticks.

2. Materials and methods

Tubers from five cultivars of cassava (*Manihot esculenta* Crantz) including Akoa Essama, I090590, 92/0326, TME/693 which are white varieties sand 01/1797 which is Yellow variety, were used in this study. Those tubers were in two groups including one produced with AM fungi and the second without AM fungi, and graciously offered by the Soil Microbiology Laboratory of the Yaoundé I University. A total of 10 groups of cassava tubers of five cultivars were obtained and used in this work. Report from the Laboratory indicated that plant roots were shown to form symbioses with fungi at the rate of 29% to 71%

2.1 Production of cassava stick

The harvested cassava tubers were washed, peeled, cut into pieces of 10 cm long, and soaked for 72 hours. Once fully fermented and tender, the cassava pieces were cleaned, and the fibers removed to obtain a paste which was then ground with a mortar and pestle to obtain a lump-free paste. The paste was then moulded with Halopegia azurea leaves, to form sticks of 40cm long, and then boiled at 100°C for 25min. the resulted sticks were then cooling, and stored for analysis [25].

2.2 Sensory evaluation and acceptability of cassava stick grown with and without AM fungi

Sensory evaluation of cassava sticks was done using seventy untrained consumers recruited among students at the Faculty of Sciences of the University of Yaoundé I, Yaoundé, Cameroon. The age of the panellists ranged from 18 to 36 years. The evaluation of the cassava stick was done in one day within 4 hours. This was done in the Food Science and Nutrition Laboratory. The panellists were credited with individual good standard sensory practices [26]. Plates containing drinking water, cassava stick for each variety, cleaner, and Schwing were provided to each panellist. They were asked to rate cassava sticks for aroma, taste, smell, texture, and overall acceptability by scoring on a nine-point hedonic scale (one means extremely unpleasant and 9 extremely pleasant). Between plates of two cassava varieties panellists were asked to rinse their mouths with water.

2.3 Nutritional analysis

Crude protein (nitrogen x 6.25) was determined using a modified Kjeldahl procedure, which uses concentrated sulphuric acid and hydrogen peroxide to decompose the sample with addition of metal catalysts [27]. Total lipids were extracted according to the method described by [28]. The crude fiber and ash content were determined after calcination by the method described by [29]. Sugar content was determined after extraction with 1.5M sulphuric acid according to the method described by [30]. For mineral content, samples were first digested in hot concentrated sulphuric acid and determined by atomic absorption spectrophotometer according to the method described by [31]. The energy content was calculated using the lipid, sugar, and protein contents following the formula described by [32].

2.4 Anti-nutritional analysis

The oxalate content of cassava stick samples was determined by titration with $KMnO_4$ after digestion of the sample in a water bath with 3M sulphuric acid for 1 hour [33]. The phytate content was determined by titration with iron III solutions after digestion of the sample with 2% chlorhydric acid for 3 hours [34]. Saponin was determined by weight difference after solvent extraction [35]. The tannin content was determined by extraction with ethanol 96% following spectrophotometric quantification using the method of [36]. The cyanide content of cassava sticks was determined according to the protocol described in [37].

2.5 Statistical analysis

The statistical analysis was carried out using a one-way analysis of variance (ANOVA) for chemical composition, and sensory acceptability data. The experiments were run in triplicate. Means were separated using Turkey's (HSD) test, and p-values < 0.05 at 95 percent confidence the interval was considered significant.

3. Results

3.1 Sensory properties of cassava stick

The result of the sensory evaluation of cassava sticks is presented in Fig. 1. The scores for the attributes color, taste, smell, texture, and overall acceptability clearly showed that cassava sticks from AM fungi plants were significantly (P<0.05) preferred than those from none AM fungi plants for the overall criteria, with respect to cassava varieties. color, taste, and general acceptability attributes showed better scores for the AE AMF variety, while the smell attribute was better for TME/693 AMF variety. In general, I090590 NAMF, AE NAMF, 01/1797 NAMF, and 92/0326 NAMF, showed the lowest score for the attributes color, smell; texture, and taste respectively.

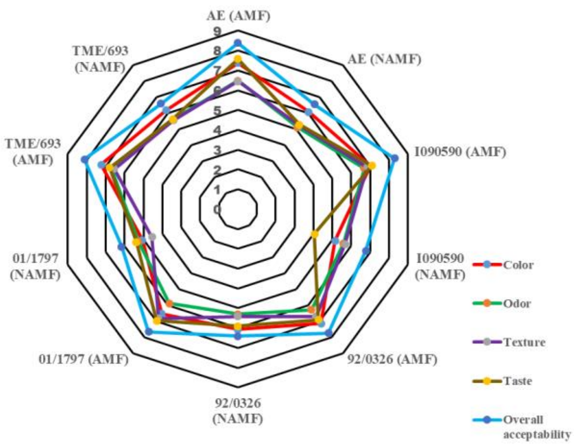

Figure 1. Sensorial properties of cassava stick as affected by AM fungi and varieties. AMF=*Arbuscular mycorrhizal* Fungi, NAMF=none *Arbuscular mycorrhizal* Fungi. AE, I090590, 92/0326, 01/1797, and TME/693 are cassava varieties.

3.2 Proximal analysis

The proximate analysis of cassava sticks from the five cassava varieties with respect to AM fungi inoculation are presented in Fig. 2. A significant increase (P<0.05) of all the nutrient content tested in the sticks from the five cassava varieties was recorded following AM fungi inoculation. The highest recorded protein content in sticks was 2.53% for the variety TME/693 with AMF, while the lowest was recorded as 0.94% for the variety 92/0326 with NAMF. The highest and lowest sugar content in sticks was recorded as 68.91% and 55% for AE AMF and TME/696 NAMF cassava varieties respectively. The highest and lowest lipid content in sticks was recorded as 0.66% and 0.32% for 01/1797 AMF and AE NAMF cassava varieties respectively. The highest and lowest fiber content in sticks was recorded as 5.02% and 1.84% for I090590 AMF and AE NAMF cassava varieties respectively. The highest and lowest ash content in sticks was recorded as 4.31% and 1.51% for 92/326 AMF and I090590 NAMF cassava varieties respectively. The highest generated energy value in cassava sticks was recorded as 291.91% for the AE AMF variety and the lowest as 230.97% for the I090590 variety.

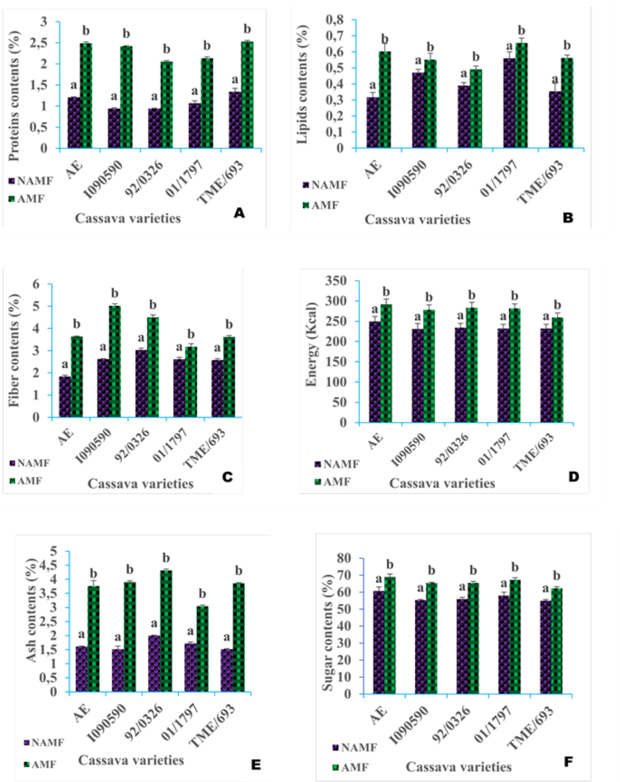

Figure 2. Protein (A), Sugar (F), Fibre (C), Ash (E), Lipid (B), and energy (D) content of cassava stick as affected by AM fungi and varieties (AMF=*Arbuscular mycorrhizal* fungi, NAMF=none *Arbuscular mycorrhizal* fungi. *AE, I090590, 92/0326, 01/1797, and TME/693 are cassava varieties*. Bars with the same letter for each variety are not significantly different at P< 0.05.).

3.3 Mineral composition of cassava sticks

The mineral analysis of cassava sticks from the five varieties with respect to AM fungi inoculation are presented *in* Table 1. A significant increase (P<0.05) of all the mineral content tested in the sticks from the five cassava varieties was recorded following AM fungi inoculation. For all the minerals, sticks from 92/0326 AMF cassava varieties showed the highest content. However, the lowest minerals content in cassava sticks varied according to the variety, with AE NAMF, TME/693 NAMF, 01/1797 NAMF, AE NAMF, and AE NAMF showing less content respectively for Ca, Mg, P, Fe, and K.

3.4 Anti-nutrient composition of cassava sticks

The anti-nutrient content of cassava sticks from five varieties with respect to AM fungi inoculation is presented *in* Table 2. A significant decrease (P<0.05) of all the anti-nutrient content tested in the sticks from the five cassava varieties was recorded following AM fungi inoculation. Cyanide always known as the poison was significantly decrease in cassava sticks following AM fungi inoculation with the rate of decrease range as 62.66%, 52.46%, 44.18%, 22.52%, and 19.38% respectively for TME/693, 01/1797, 92/0326, AE and I090590 varieties. Cassava sticks from TME/693 variety recorded the best decrease in both cyanide and oxalates, respectively at the rate of 38.55 and 70.77%. On the other hand, 92/0326 variety showed the best decrease in Phytate and tannin, while 01/1797 variety show the best decrease for tannin.

4. Discussion

Cassava tubers are raw materials for both traditional and modern industries with a range of novel derived products, including livestock feeds, ethanol, starch, and numerous other derivatives [38]. In most African countries, Cassava has two main forms of consumption including peeled and cooked tubers accounting for about 30% of production, and the remaining 70% is processed into various derived products like cooked fermented pastes locally (bobolo). Fermented products are the major form of cassava consumed in large parts of Africa, accounting for almost 75% of cassava-based foods [39]. The study revealed significantly better sensorial properties of fermented paste cassava sticks with respect to varieties as well as AM fungi status of the plant-producing tubers. The appreciation was based on

Table 1. Mineral content (mg /kg) of cassava stick as affected by AM fungi and varieties.

Varieties	Ca	Mg	P	Fe	K
AE (AMF)	4250.72±0.36[b]	3916.41±0.69[b]	1041.68±1[b]	2810±0.11[b]	38.25±1.01[b]
AE (NAMF)	2614.23±0.52[a]	2570.28±0.81[a]	782.81±1.03[a]	961[a]	12.28±0.29[a]
I090590 (AMF)	4115.39±0.77[b]	3780.99±0.53[b]	1348.59±1.17[b]	1858±0.11[b]	52.26±0.96[b]
I090590 (NAMF)	3374.99±0.01[b]	2609.62±0.54[a]	1086.81±1.03[a]	1153[a]	34.59±0.64[a]
92/0326 (AMF)	5187.65±0.83[a]	4210.14±0,95[b]	1542.91±1[b]	2820±0,11[b]	27.62±0.68[b]
92/0326 (NAMF)	3163.72±0.37[b]	2521.46±0.7[a]	1324.75±1.4[a]	1987±0.11[a]	12.78±0.58[a]
01/1797 (AMF)	4656.02±0.27[b]	3809.63±0.61[b]	1175.38±1.32[b]	2307[b]	64.15±0.51[b]
01/1797 (NAMF)	3025.07±0.3[a]	2369.91±0.42[a]	714.56±0.78[a]	1153[a]	56.94±0.58[a]
TME/693 (AMF)	4423.68±0.58[b]	3529.39±0.59[b]	1067.84±0.89[b]	2500[b]	54.75±0.96[b]
TME/693(NAMF)	2423.7±0.31[a]	2028.55±0.85[a]	969.41±0.71[a]	1025±0.11[a]	44.59±0.49[a]

AMF=*Arbuscular mycorrhizal* fungi, NAMF=none *Arbuscular mycorrhizal* fungi. AE, I090590, 92/0326, 01/1797, and TME/693 are cassava varieties. Data in Colum for each variety followed by the same letter are not significantly different at $P< 0.05$.

Table 2: Anti-nutrient content (mg/kg) of cassava stick as affected by AM fungi and varieties.

Varieties	Cyanides	Oxalates	Phytates	Tannins	Saponines
AE (AMF)	269.93±0.7[a]	0.46±0.02[a]	0.42±0.01[a]	0.05±0.04[a]	15.38[a]
AE (NAMF)	334.33±0.41[b]	0.78±0.01[b]	0.47±0.01[b]	0.09[b]	19.24[b]
I090590 (AMF)	280.27±0.42[a]	0.86[a]	0.42[a]	0.08[a]	16.9±0.1[a]
I090590 (NAMF)	343.33±1.33[b]	1.49±0.05[b]	0.63±0.01[b]	0.1[b]	20.36±0.29[b]
92/0326 (AMF)	172±0.8[a]	0.29[a]	0.32±0.03[a]	0.01[a]	13.1[a]
92/0326 (NAMF)	248.3±0.1[b]	0.54±0.01[b]	0.55[b]	0.07[b]	17.52±0.64[b]
01/1797 (AMF)	162.87±0.64[a]	0.54±0.01[a]	0.35±0.01[a]	0.08[a]	12.19±0.26[a]
01/1797 (NAMF)	247.6±0.8[b]	0.84[b]	0.52±0.01[b]	0.091[b]	17.1±1.41[b]
TME/693 (AMF)	150.07±1.3[a]	0.37±0.01[a]	0.39[a]	0.074[a]	15.23±0.21[a]
TME/693 (NAMF)	244.21±1.76[b]	1.26[b]	0.58[b]	0.08[b]	19.14[b]

AMF= *Arbuscular mycorrhizal* fungi, NAMF=none *Arbuscular mycorrhizal* fungi. *AE, I090590, 92/0326, 01/1797, and TME/693 are cassava varieties.* Data in Colum for each variety followed by the same letter are not significantly different at $P< 0.05$.

attributes including color, taste, smell, texture, and overall acceptability which were both better scored for sticks from AM fungi plant origin (Fig. 1). Cassava is known to form a symbiosis with AM fungi [21]. Many researchers agree that texture is a key attribute of consumer acceptance of foods and therefore an important step in quality assessment [40-41]. In general, one of the most consumed cassava products locally is cassava sticks generally as food supplements in households [42]. A study on cassava sticks from inoculated plants obtained high scores with respect to quality and sensory analysis of attributes assessed: color, texture, smell, and overall acceptability [43]. Previous studies showed that diversity of quality characteristics may lead to large variability in the processing, use, and quality of cassava by-products including fermented paste cassava sticks. Moreover, it has been demonstrated that the quality and acceptability of a by-product gari significantly varied in different studies with respect to cassava varieties [44,19, 45]. Another outcome from this work shows that protein, lipid, fibers, Ash, and sugar content significantly increase in cassava sticks with respect to varieties and AM fungi inoculation (Fig. 2). A similar observation was also recorded for minerals Ca, Mg, P, Fe, and K (Table 1). AM symbiosis is a kind of relationship between plants and fungi with a range of consequences on plant physiology including nutrient uptake, and the impact of plant metabolism with repercussions on foods. Observation from this work is similar to that recorded while studying the interaction between AM fungi and cassava showing improvement in the host physiology, and biomass production [21, 9]. The principal role of AM fungi in the symbiotic system is the improvement of mineral acquisition, especially P and the others. Even if the mechanisms are still to be fully clarified, researchers believed that AM plants are more nutrient-dense [46]. Study related to the interaction between potato plant and AM fungi shows an increase in various biochemical compound including protein and sugar [47]. A significant increase of P, Ca, and Mg content was noted in cassava flour from AM fungi inoculated plant compare to the control none inoculated showing the possible implication of this symbiosis to the uptake of this nutrient. Nutrients sugar and minerals are both known to alter the taste while proteins are known to alter the texture of foods and surely contribute to the global acceptability of a given food by consumers. Moreover, researchers agree that texture is a key characteristic of food sensorial evaluation and therefore an important step in quality assessment [40]. Looking that way, the consequence of the improvement of those nutrients in AM fungi cassava tubers is the best acceptability of sticks, with respect to the varieties because of their genetics which is different from one plant to another. Cassava belongs to a group of plants known to produce and store secondary metabolites with anti-nutrient properties. Another outcome of this work shows that anti-nutrient content significantly decreases in cassava sticks with respect to varieties and AM fungi treatment (Table 2). Those antinutrients include cyanides, phytates, oxalates, saponins, and tannins. Cyanide which is believed to be the most redoubtable poison produced by cassava plants significantly decrease in cassava sticks following AM fungi inoculation with a rate range from 62.66% for TME/69352 variety to 19.38% for I090590 variety. A study on cassava plants showed that inoculation of these plants with AM fungi decreases the content of Cyanide as well as phytates, oxalates, and saponins in tubers [14]. The decrease of secondary metabolites in cassava sticks is the direct consequence of AM fungi inoculation, which impacts the physiology of the cassava plant during its growth [48].

5. Conclusions

This study showed a great variation in the sensorial quality of Cassava sticks with respect to varieties and AM fungi inoculation. The nutritional composition of cassava sticks was also shown to vary with respect to varieties and AM fungi inoculation. The work also shows that the antinutritional component of cassava sticks significantly decreases with respect to AM fungi inoculation and varieties. The use of AM fungi as a fertilizer for cassava production should be recommended to producers for healthy products. Future research should be directed to others cassava by-products and varieties.

Authors' contributions

Conceptualization, investigation, draft preparation, and validation of this document, M.M.G.G., A.**S.,** S.F.T., S.F.T., N.**D.,** F.E., F.R.; Carried out lab analyses, sensorial analyses, reviewing and editing the document, E.D., L.N.N.D., K.N.B.D., N.N.A.L.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflict of interest.

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