Journal of Agricultural Science and Technology B 10 (2020) 308-316
doi: 10.17265/2161-6264/2020.05.005

Analysis of Nutrient Profile of Finger Millet (*Eleusine coracana* (L.) Gaertn.) for Baby Food Formulation Using Pigeon Pea (*Cajanus cajan* (L.) Millsp.) as Protein Source

Britany Font[1], Anne Osano[2], Paul Kimurto[3], Cyprian Syeunda[3], Jaya Manyasi Tracyline[3] and Joshua Ogendo[3]

1. Department of Science and Technology, Faculty of Biotechnology, Inter American University, Aguadilla, Puerto Rico

2. Department of Natural Sciences, Faculty of Biology, Bowie State University, Bowie, MD, USA

3. Department of Crops, Faculty of Horticulture & Soils, Egerton University, Kenya

Abstract: Finger millet (*Eleusine coracana* (L.) Gaertn.) is a drought resistant crop with potentially tremendous but under-explored source of nutraceutical properties as compared to other regularly consumed cereals in the era of drawback of nutritional security, these characteristics must be harnessed to develop finger millet as a novel functional food. Under-nutrition caused by inadequate diets, and other factors that influence nutritional status, is the underlying factor in 45% child deaths. In Kenya only 25% of young children are fed adequately diverse diets. The main objective of this study was to prepare baby food formulas using finger millets with pigeon peas as protein source and to analyze their nutritional profiles. Two finger millets varieties (i) Snapping Green Early, low altitude and medium altitude varieties and (ii) U-15) were studied to determine effects of environment on nutrient profiles. This study showed that Snapping Green Early had better nutrient profiles (12.13% protein and is high in Ca, Mg, Fe, Zn and P) than U-15 (11.69% protein and lower nutrients (Ca, Mg, Fe, Zn and P)), and hence was selected for use in the malting process as best variety. As expected, the pigeon peas had the highest protein value (21%). The samples malted for 72 h resulted in reduction of tannin concentration from 0.091% to 0.03% and the amount of nutrients (Ca, Mg, Fe and Zn) doubled and in fact the protein profile increased by 8.31%. The appropriate ratio for the formulation of the baby food was 70:30. The composting resulted in 18.5% increase in protein.

Key words: Malnutrition, baby food, finger millet, protein source, nutrient profile, pigeon pea.

1. Introduction

Finger millet (*Eleusine coracana* L.) is a plant that serves as cereal and is grown mostly in areas of Africa where the climatic conditions are adverse (Fig. 1). This crop can be planted in areas where the soils lack nutrients and water. Given these high-stress conditions, the plant has the capacity to survive in less favorable conditions [1]. It does not require any storage standards and its nutritional value increases with increased extreme climatic conditions [2]. Finger millet is rich in minerals, nutrients like Ca, Fe, P, K and Zn. It is cultivated in diverse places where food shortages are alarming in rural areas [3]. Ca deficiency in rural populations has led to an alternative interest in grains such as finger millet because of its high Ca content and ability to prevent Ca deficiency [4]. In Kenya, finger millet is a local crop and is grown in rural areas in Kenya and many African countries including Uganda, Tanzania and Ethiopia. It is used in several villages in Kenya to prepare four types of food: ugali (hard papilla), uji (thin papilla), togwa (saccharified drink) and pombe (alcoholic drink) [5]. First, they are milled and then go through commonly used processing techniques including malting, fermentation and thermal processing [4]. Fermentation

Corresponding author: Britany Font, undergraduate student, research field: REU trip to Kenya in food security.

(a) (b) (c) (d)

Fig. 1 Snapping Green Early genotype plant (a), Snapping Green Early seeds (b), U-15 genotype seeds (c) and pigeon pea protein seeds (d).

helps to improve nutritional values by eliminating the anti-nutrients, helping in turn to preserve the product and the nutritional accessibility of the cereal. Fermenting cereals together with pulses result in a balance between the macro- and micro-nutrients of the cereals that go through the fermentation process [6]. Cereals are important sources of protein for human nutrition but have low quality due to limitations in the amounts of essential amino acids, notably lysine. Although finger millet is a cereal it does not have the necessary amount of protein compared to other cereals. Undernutrition and food insecurity increase, has accelerated risks of severe diseases [7]. In Kenya for example, between 2007 and 2008, because of the shortage of food and malnutrition, there was an increase in the infant mortality rate [8]. Food security and/or the nutritional status of children decreased in most rural populations which caused chronic malnutrition as shown by nutritional survey among infants aged 6-59 months in two villages in Kibera, where the Kenya Medical Research Institute/Centers for Disease Control and Prevention conducted population-based surveillance for the syndromes of infectious diseases [8]. In a sample of 1,310 children from household demographics, food availability and infant feeding practices resulted in 47.0% delay in growth for infants and 11.8% low weight, 23.4% of chronic growth retardation and severe weight loss in 0.6% of infants [8]. Families with infants between 36 months and 47 months of age had 58.0% of development problems [8]. This was because the nutritional value was below the required rate. Another study conducted in Chroma revealed that only 40% of 388 children between 24 months and 59 months had a good diet with the necessary nutrients for a safe development and 60% had poor nutrition and food insecurity [9].

Pigeon pea is a legume that acts as a protein option for poor communities because its seeds are rich in protein. This plant can grow in about 50 countries and can be prepared into various meals and served as substitute to cowpeas in tropics and sub-tropics. It also provides fuel wood and fodder in both Africa and Asia [10]. As a protein source, it can be used in combination with different cereals [11]. Although it is drought tolerant, it has high nutritional value with proteins, vitamins, minerals. It has been considered as one of the best solutions to protein-calorie malnutrition in the developing world. Pigeon pea is abundant in protein, making it an ideal supplement to traditional cereal, banana or tuber-based diets of most Africans who are generally protein-deficient [12]. The chemical composition of the pigeon pea seed shows that it can have 20%-22% protein. One hundred grams (100 g) net of pigeon pea has 336 mg Ca, 1.4 g of fat, 61.4 g of carbohydrates, 100 mg of Ca, 400 mg of P, 5.2 mg of Fe and vitamin A. Considering that the cultivation of this legume is economical and easy, it is a good option for protein supply in Kenya, Africa. Pigeon pea seed can be used whole, sliced or in flour as a supplement in baby food [10]. It also acts as good vegetable food source during dry season in arid areas [13]. The aim of this study was therefore to determine the nutritional profile of two finger millet varieties in the dry land areas of Kenya and improve their nutrient profiles using pigeon pea as protein source and formulate baby food that contributes to improved nutrition of rural children in Kenya.

2. Materials and Methods

This study was conducted at Egerton University located in Nakuru, County Rift Valley in Kenya. Analysis was performed at the molecular laboratory and soils laboratory, Department of Crops, Horticulture and Soil Sciences, food and science laboratory in Department of Dairy and Food Sciences and in the Faculty of Agriculture. The finger millet was grown in two sites: Bomet County, the medium altitude agro-ecological zone and Koibatek, Baringo County, the lower altitude agro-ecological zone. Bomet has a warm climate with an altitude of 2,044 m and is about 181.7 km away from the Egerton University while Barongo (Koibatek) is drier with an altitude of 1,823 m. It is about 60 km from Egerton University.

2.1 Plant Materials

Two varieties of finger millet were obtained from Egerton University Agro-Science Park Seed Unit (Snapping Green Early) and Kenya Agricultural and Livestock Research Organization (KALRO) (U-15). Pigeon pea was obtained from the same seed unit. Snapping Green Early is a medium to late maturity crop and is more adapted to medium altitude areas while U-15 is an early maturing and more adapted to low altitude areas. Snapping Green Early, for example, has characteristics that make it easy to collect, and is also the product of various genetic crosses over time which is specific to its red grain. U-15 has a fairly favorable growth time, so a genetic crossing with Snapping Green Early can be significantly favorable for farmers and in turn increase genetic variability.

2.2 Determination of Condensed Tannin Content

The condensed tannin content of the finger millet and compositing flours was determined by the use of the vanillin-HCl method [14]. Four hundred milligrams (400 mg) of flour was extracted with 20 mL of 100% methanol for 1 h at room temperature. Samples were centrifuged for 10 min at 1,200 rpm using a temperature-controlled centrifuge set at 25 °C. Three replicate supernatants were obtained. The extracts and the vanillin reagent (4% HCl in methanol and 0.5% *w*/*v* vanillin in methanol) were maintained at 30 °C in a thermostat-controlled water bath before being mixed with the reactants. Sample extracts (1 mL) were mixed with 5 mL of vanillin reagent in test tubes and then maintained at 30 °C in the water bath for 20 min. Sample blanks in which the vanillin reagent was replaced by 4% HCl in methanol were included. Absorbance at 500 nm was measured where "catechin" was used as a standard.

2.3 Determination of Protein Content

Protein of the finger millet and compositing flours was determined by micro-Kjeldahl procedure [15] using a conversion factor of 6.25. The crude protein (CP) content was determined by digesting the samples at high temperature with concentrated sulphuric acid, sodium sulphate and metal catalyst followed by neutralization using a suitable alkali to free ammonia gas which was trapped by hydrochloric acid with an indicator for color change. The excess hydrochloric acid was back titrated against sodium hydroxide.

The CP was calculated as follows:

% Nitrogen = mL standard acid × N of acid – mL blank × N base – mL standard base × N base × 1.4007 weight of sample in gram

$$CP = 6.25 \times \%\ nitrogen \quad (1)$$

where 6.25 is the conversion factor.

2.4 Preparation of Finger Millet Flour

The malting of the finger millet was carried out with modification as described by Mbithi-Mwikya *et al.* [16]. Finger millet grains (1 kg) were washed three times and steeped in 2 L water for 24 h. Water was changed after every 6 h during steeping. The grains were then washed after steeping and germinated in ventilated cupboards for 2 d at an ambient temperature of 28 °C. Water was sprinkled on the germinating seeds regularly and then occasionally mixed. The malted finger millet grains were removed and dried in an oven at 48 ± 2 °C for 24 h. The grains were milled using a Brabender Quadrumat Experimental Mill (Duisburg, Germany) fitted with a 500 µm opening screen to give whole grain flour and stored at 9-10 °C until further analysis.

2.5 Determination of Moisture Content

The moisture content of the finger millet samples was determined using oven-drying to a constant weight at 103 °C. Five grams (5 g) of the sample was exposed to a single stage air for 3 h. The moisture content was calculated as the loss in weight expressed as a percent of the original weight of the sample [15].

% Moisture weight = weight of water in sample – weight of wet sample × 100 (2)

2.6 Determination of Ash Content

The ash content of the finger millet and compositing flours was determined by oven-drying at 550 °C for 8 h, followed by decomposition in a muffle furnace. Two grams (2 g) of sample was introduced into a crucible and put into an oven for removal of moisture at 105 °C for 24 h. This was followed by ashing in a muffle furnace at 550-620 °C for 6 h [15].

The ash content was determined as follows:

% Ash (dry basis) = weight after ashing – (tare weight of crucible original sample weight) × dry matter coefficient × 100 (3)

where, dry matter coefficient = % solids × 100.

3. Results and Discussion

Based on Fig. 2, pigeon pea flour had a high amount of Ca, 10.23 ppm, Mg, 4.96 ppm, K, 11.69 ppm, P, 3.87 ppm, Fe, 5.02 ppm, Mn, 0.34 ppm and Zn, 3.49 ppm. These values make pigeon pea flour a good candidate for baby food formulation. The high nutritional level may be related to the low amount of anti-nutritional components also known as tannins, phytates, phenols and enzyme inhibitors [17]. Conversely pigeon pea has high protein content (Fig. 3) which can be composited with a cereal to formulate a complementary food that can curb protein energy malnutrition. For the low altitude (Fig. 4), Snapping Green Early indicated a favorable value of anti-nutritional content (tannin) 0.07% compared to the U-15 sample with 0.139%. Snapping Green Early results showed a protein content of 12.13% and U-15 of 11.69%. Snapping Green Early had a nuitritinal moisture content of 10.07% while U-15 of 9.39%. The ash content percentage for Snapping Green Early was 3.41% and for U-15, it was 3.32% (Fig. 4). The mineral profile (Ca, P, Fe, Zn, Mn and Mg) of Snappping Green Early was superior as compared to U-15 (Fig. 5). This underscores the effect of environment on nutrient composition of finger millet variety. The anti-nutrient content for both samples was not high, showing Snapping Green Early with the lowest percentage value of 0.091% and U-15 with 0.12%. The protein percentage was significantly lower than the low altitude samples for Snapping Green Early, 5.13% and U-15, 1.17%. For medium attitude (Fig. 6), the nutritional moisture content was 6.48% for Snapping Green Early and 9.06% for U-15; the ash content for Snapping Green Early was 2.87% and 2.4% for U-15 (Fig. 6). Snapping Green Early therefore proves to have a better nutritional profile than U-15, having a higher value in Ca (25.04 ppm), Mg (8.25 ppm) and K (9.23 ppm). U-15 was highlighted in the P value with 4.31 ppm and Fe with 14.46 ppm. The nutritional value of Mg and Zn was low for both and P especially for Snapping Green Early with 0.95 ppm in nutritional value. The high nutritional level must be related to the low amount of anti-nutritional components also known as tannins, phytates, phenols and enzyme inhibitors [17] (Fig. 7). The samples with the best nutritional value and protein levels were selected for the malting process. Being Snapping Green Early selected for the 24-hour, 48-hour and 72-hour process, the 48-hour sample of malting was the best since the protein value was well marked with 21.88%. The tannin content, moisture content and ash content were low in all samples, however, the best was 48 h. Malting process has been reported to improve the nutritional quality of seeds by increasing the contents and availability of essential nutrients and lowering the levels of anti-nutrients. It has been shown that a well-designed malting/germination process can significantly reduce these anti-nutrients and enhance the nutrient availability [16] (Fig. 8). The nutritional profile of the Snapping Green Early samples in the malting process for 24, 48 and 72 h obtained considerable values in all the samples. However, the sample of 72 h was selected since in Ca it obtained 23.51 ppm, Mg 6.17 ppm, K 5.15 ppm, P 1.85 ppm, Fe 14.53 ppm, Mn 2.34 ppm and Zn 3.45 ppm, with remarkably higher and acceptable results unlike the samples of 24 h and 48 h. The nutritional value of the samples increases as the anti-nutrients are removed during the hours that it is exposed to the malting. According to Ref. [18], the malting helps to hydrolyze the soluble to insubstantial protein and acts on the tannin protein complex. Tannins are capable of forming a non-digestible protein-tannin complex, through hydrophobic interactions and hydrogen bonding that likely resulted in reduced digestibility of finger millet protein. The low molecular weight monomers that are formed after the decomposition of condensed tannins cannot exert stearic effects on proteins and, in the process, would result in increased digestibility of proteins [18] (Fig. 9). The nutritional profiles with the different ratios of the Snapping Green Early compost with the high protein source pigeon pea were highly favorable. The selected ratio was 70:30 due to the high protein percentage of 38.94%. The sample provided the expected nutritional and protein value. This is highly related to the low percentage of tannin 0.14% compared to the sample 100:00 and 80:20 with 0.21%. The nutritional value of Ca, Mg, K, P, Fe, Mn and Zn improved since through the malting/germination process the anti-nutritional factors were decreased (Fig. 10).

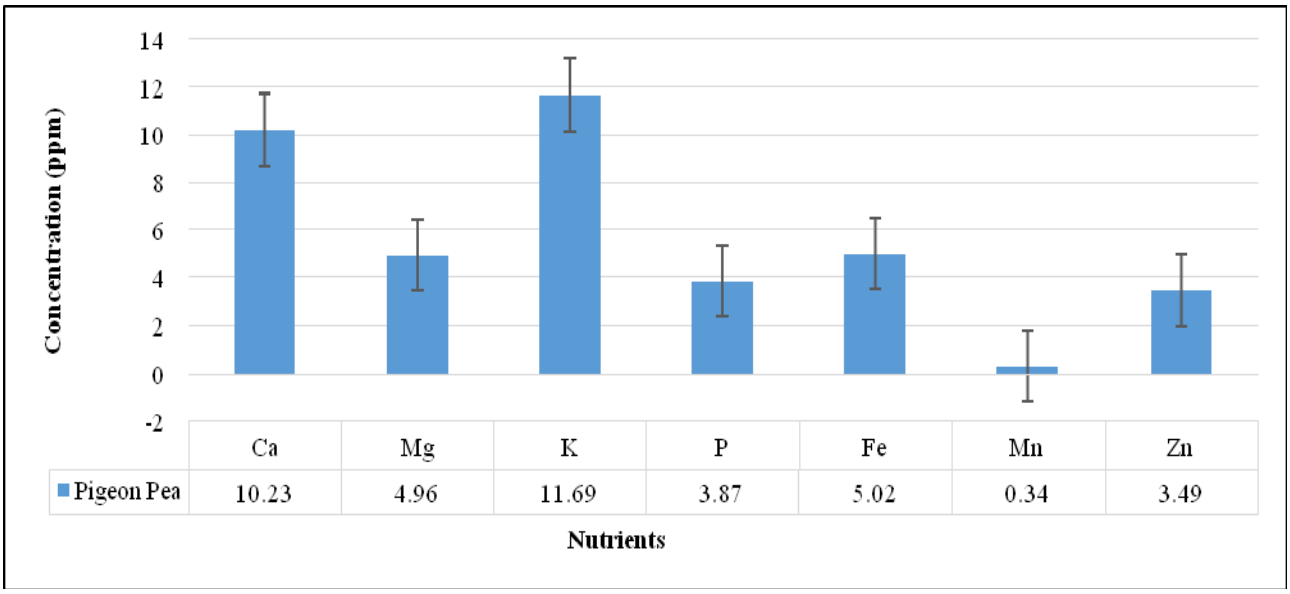


Fig. 2 The minerals profile of pigeon pea.

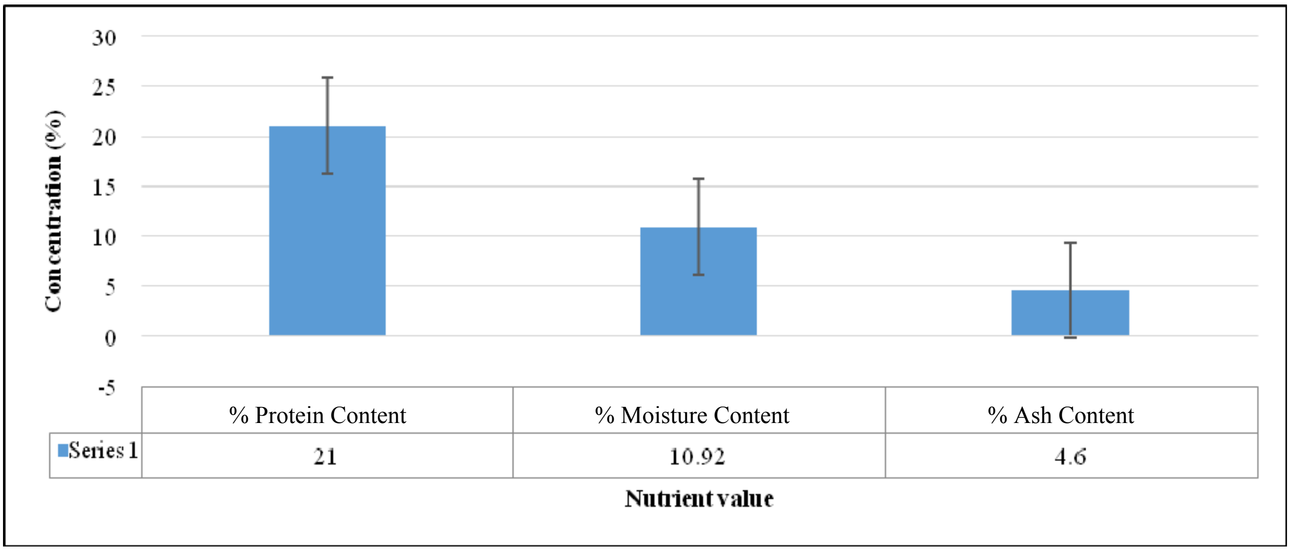


Fig. 3 **% Protein content, % moisture content and % ash content of pigeon pea.**

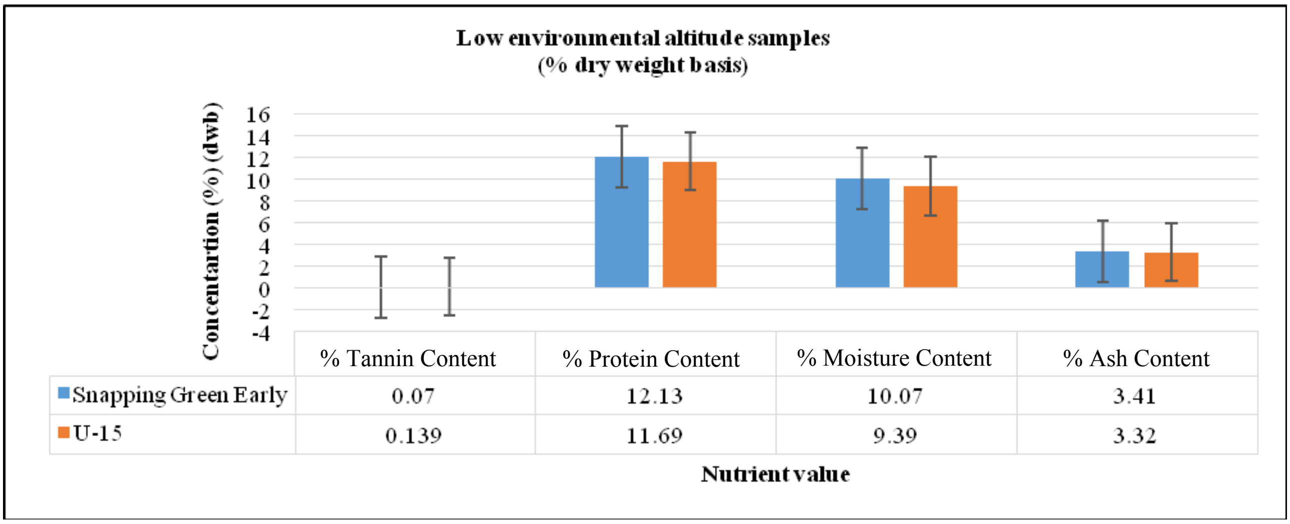


Fig. 4 **Protein profile of two varieties of finger millet in low environmental altitude.**

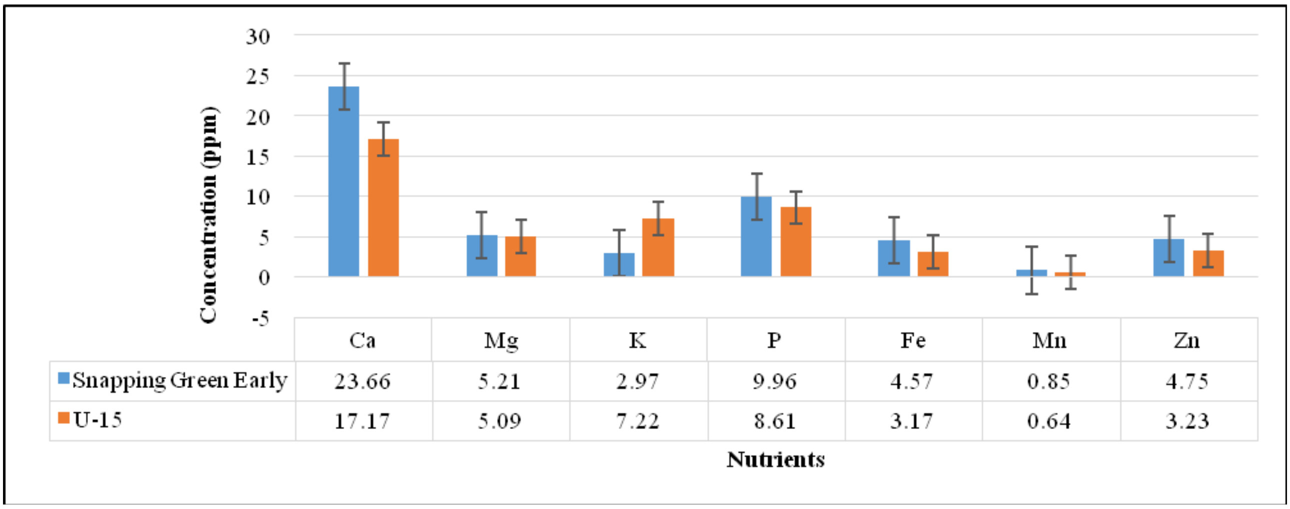
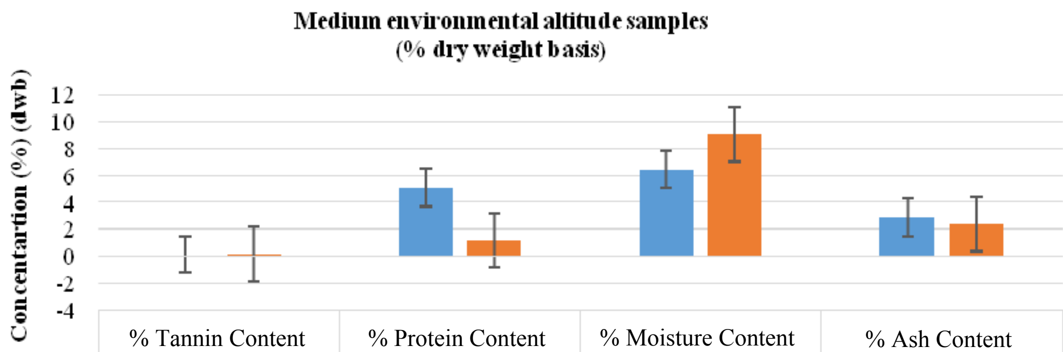


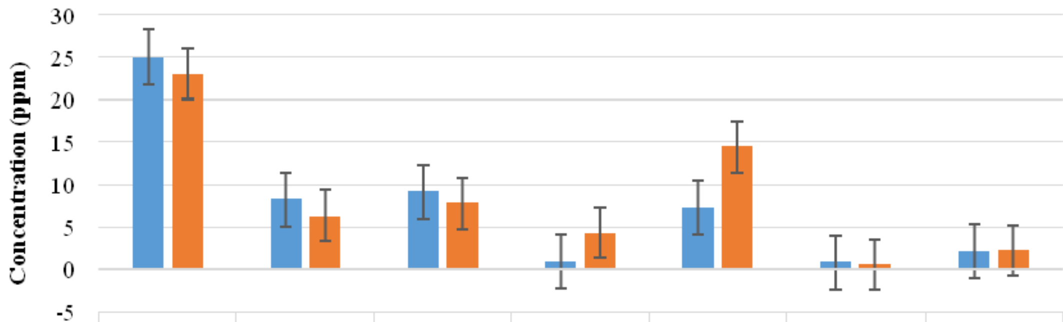
Fig. 5 **Nutrient profile of two varieties of finger millet in low altitude environment.**



	% Tannin Content	% Protein Content	% Moisture Content	% Ash Content
Snapping Green Early	0.091	5.13	6.48	2.87
U-15	0.12	1.17	9.06	2.4

Nutrient value

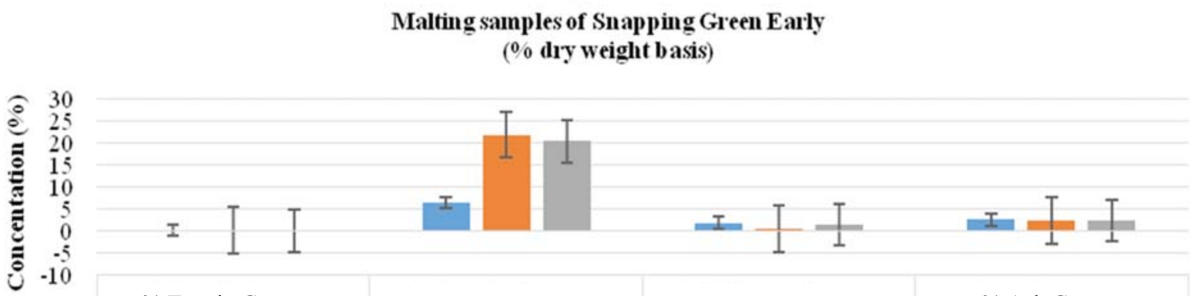
Fig. 6 Protein, moisture and ash contents of the two varieties of finger millet in medium altitude.



	Ca	Mg	K	P	Fe	Mn	Zn
Snapping Green Early	25.04	8.25	9.23	0.95	7.31	0.86	2.16
U-15	23.1	6.37	7.78	4.31	14.46	0.59	2.32

Nutrients

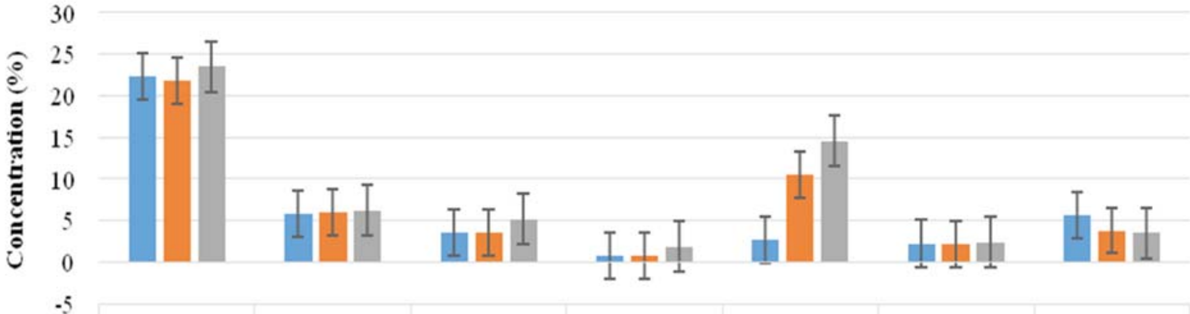
Fig. 7 Nutrient profile of the two varieties of finger millet in medium altitude environment.



	% Tannin Content	% Protein Content	% Moisture Content	% Ash Content
24 Hrs	0.05	6.44	1.77	2.55
48 Hrs	0.036	21.88	0.36	2.37
72 Hrs	0.03	20.44	1.35	2.33

Nutrient value

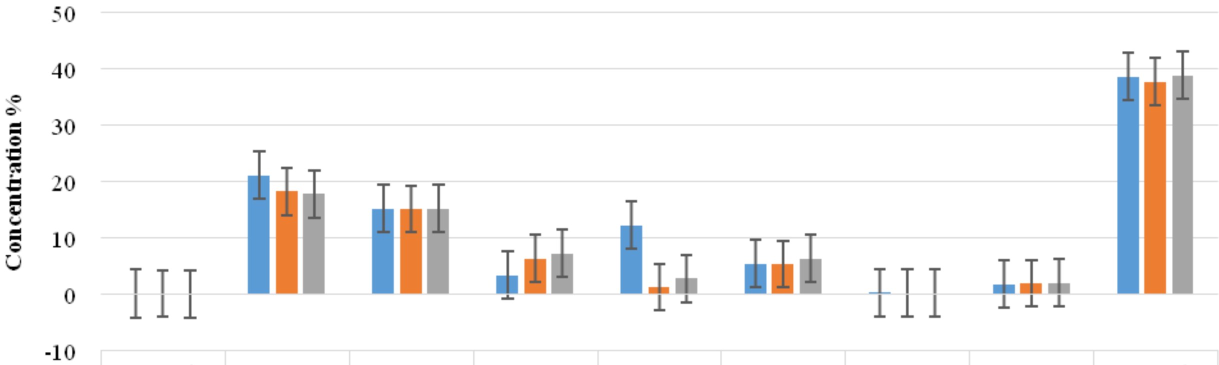
Fig. 8 Protein, moisture and ash content of Snapping Green Early genotype of finger millet.



	Ca	Mg	K	P	Fe	Mn	Zn
24Hrs	22.36	5.81	3.47	0.69	2.63	2.22	5.63
48Hrs	21.78	5.94	3.54	0.71	10.48	2.14	3.77
72Hrs	23.51	6.17	5.15	1.85	14.53	2.34	3.45

Nutrients

Fig. 9 Nutrient profile of malting samples of Snapping Green Early genotype of finger millet.



	%Tannin Content	Ca	Mg	K	P	Fe	Mn	Zn	%Protein Content
■	0.21	21.15	15.33	3.48	12.35	5.53	0.38	1.87	38.72
■	0.21	18.3	15.23	6.45	1.3	5.43	0.27	2.08	37.84
■	0.14	17.87	15.25	7.35	2.85	6.46	0.34	2.05	38.94

Nutrients

■ 100:00 ■ 80:20 ■ 70:30

Fig. 10 Nutrient profile with different ratios of Snapping Green Early genotype composting with pigeon pea

4. Conclusions

The combination of finger millet and pigeon pea through malting and composting can improve the nutritional quality of finger millet. Based on the results, Snapping Green Early genotype can be used in combination with pigeon pea for the formulation of baby food to help prevent malnutrition in Kenya, Africa.

5. Recommendations

In future this research maybe expanded to include bio-technology approaches such as genetic engineering to genetically modify and improve finger millet. The focus of this new project will be on the search for genes that produce anti-nutrients (tannin) in finger millets plants. By suppressing these genes, crops with greater nutritional value will be obtained.

Diseases are also a big problem for finger millet crops; focusing on genes that can provide resistance to these diseases can improve the production of the crop.

Acknowledgments

Special thanks go to Dr. Anne Osano for allowing the first author to be part of this research experience, and the National Science Foundation (NSF) for funding this research opportunity.

References

[1] Ulaganathan, V., and Nirmalakumari, A. 2015. "Finger Millet Germplasm Characterization and Evaluation Using Principal Component Analysis." *SABRAO Journal of Breeding & Genetics* 47 (2): 79-88.

[2] Negi, S., Kumar, V., and Bhatt, A. 2017. "Morphological Characterization and Genetic Analysis of Finger Millet (*Eleusine coracana* (L.) Gaertn.) Germplasm." *International Journal of Bio-Resource & Stress Management* 8 (3): 469-72.

[3] Karad, S. R., and Patil, J. V. 2013. "Assessment of Genetic Diversity among Finger Millet (*Eleusine coracana* L.) Genotypes." *Int. J. Int Sci. Inn. Tech. Sec. C* 2 (4): 37-43.

[4] Saleh, A. S. M., Zhang, Q., Chen, J., and Shen, Q. 2013. "Millet Grains: Nutritional Quality, Processing, and Potential Health Benefits." *Comprehensive Reviews in Food Science and Food Safety* 12 (3): 281-95.

[5] Kubo, R. 2016. "The Reason for the Preferential Use of Finger Millet (*Eleusine coracana*) in Eastern African Brewing." *Journal of the Institute of Brewing* 122 (1): 175-80.

[6] Palanisamy, B. D., Rajendran, V., Sathyaseelan, S., Venkatesan, B. P., and Bhat, R. 2012. "Enhancement of Nutritional Value of Finger Millet-Based Food (Indian Dosa) by Co-fermentation with Horse Gram Flour." *International Journal of Food Sciences and Nutrition* 63 (1): 5-15.

[7] Hubert, J., Berger, M., Nepveu, F., Paul, F., and Daydé, J. 2008. "Effects of Fermentation on the Phytochemical Composition and Antioxidant Properties of Soy Germ." *Food Chemistry* 109 (4): 709-21.

[8] Olack, B., Burke, H., Cosmas, L., Bamrah, S., Dooling, K., Feikin, D. R., and Breiman, R. F. 2011. "Nutritional Status of Under-Five Children Living in an Informal Urban Settlement in Nairobi, Kenya." *Journal of Health, Population, and Nutrition* 29 (4): 357.

[9] Hoffman, D., Cacciola, T., Barrios, P., and Simon, J. 2017. "Temporal Changes and Determinants of Childhood Nutritional Status in Kenya and Zambia." *Journal of Health, Population & Nutrition* 36 (1): 27. https://doi.org/10.1186/s41043-017-0095-z.

[10] Carmen Lucia Navarro, V., Diego Restrepo, M., and Jaime Perez, M. 2014. "Pigeon Pea (*Cajanus cajan*): An Alternative in the Food Industry." *Biotecnología En El Sector Agropecuario y Agroindustrial* 12 (2): 197. (in Spanish)

[11] Bashir, S., and Ahmad, B. 2019. "Effect of Pigeon Pea Green Maturing and Nitrogen on Performance of Wheat Crop." *Sarhad Journal of Agriculture* 35 (2): 467-75.

[12] Yamanura, L. R., Muniswamy, S., Girish, G., Mahiboobsa, M., and Ramesh. 2018. "Molecular Diversity and Phenotypic Characterization of A, B and R Lines in Pigeon Pea (*Cajanus cajan* (L.) Millsp.)." *Legume Research: An International Journal* 41 (1): 1-11. https://doi.org/10.18805/LR-3636.

[13] Talari, A., and Shakappa, D. 2018. "Role of Pigeon Pea (*Cajanus cajan* L.) in Human Nutrition and Health: A Review." *Asian Journal of Dairy & Food Research* 37 (3): 212-20.

[14] Deshpande, S. S., and Cheryan, M. 1985. "Evaluation of Vanillin Assay for Tannin Analysis of Dry Beans." *Journal of Food Science* 50 (4): 905-10.

[15] AACC International. 2000. *Approved Methods of the American Association of Cereal Chemists*, 11th ed. Methods 44-15a and 46-10.01. St. Paul: The Association.

[16] Mbithi-Mwikya, S., Van Camp, J., Yiru, Y., and Huyghebaert, A. 2000. "Nutrient and Antinutrient Changes in Finger Millet (*Eleusine coracan*) during Sprouting." *LWT-Food Science and Technology* 33 (1): 9-14.

[17] Ambuko, J., Onwonga, R., Nyongesa, O., and Shibairo, S. I. 2014. "Variation of Nutritional and Anti-nutritional Contents in Finger Millet (*Eleusine coracana* (L.) Gaertn.) Genotypes." *IOSR Journal of Agriculture and Veterinary Science* 7 (11): 6-12.

[18] Syeunda, C. O., Anyango, J. O., Faraj, A. K., and Kimurto, P. K. 2020. "*In Vitro* Protein Digestibility of Finger Millet Complementary Porridge as Affected by Compositing Precooked Cowpea with Improved Malted Finger Millet." *Journal of Food Science and Technology* 1-10. https://doi.org/10.1007/s13197-020-04569-1. (in Spanish)