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Nutritional Qualities of Ginger Mutant Lines Grown in the Humid Tropical Agroecology of Nigeria

M. N. Abua[1*], M. A. Ittah[1], E. E. Obok[1], G. A. Iwo[1], R. E. Edugbo[2] and C. O. Amadi[3]

[1]Department of Crop Science, University of Calabar, P.M.B. 1115 Calabar, Cross River State, Nigeria.
[2]Department of Agronomy, Michael Okpara University of Agriculture Umudike, P.M.B. 7267, Umuahia, Abia State, Nigeria.
[3]National Root Crop Research Institute, Umudike, Abia State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors jointly designed, reported the study and their findings respectively. All authors read and approved the final manuscript

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ABSTRACT

The present study was aimed to determine the variations in nutritional qualities of 15 mutant lines and two landraces of ginger (*Zingiber officinale*). Fifteen (15) gamma (γ)-ray induced mutants lines and two landraces of ginger were planted in 2017 early cropping season in the Teaching and Research Farm, Department of Crop Science, Faculty of Agriculture, Forestry and Wildlife Resources Management, University of Calabar, Calabar, Nigeria. To evaluate the nutritional qualities of these seventeen ginger genotypes at maturity, proximate analysis was carried out in the Biochemistry Laboratory of the National Root Crop Research Institute Umudike, Abia State, Nigeria. Using standard and official protocols of the Association of Official Analytical Chemists (AOAC). Results showed that the ginger lines varied significantly ($P < 0.01$) in all their proximate attributes. The moisture content ranged from 10.13% (UG1) to 12.95% (UG2). Mean dry matter was 88.89%; UG1 and UG2 had the highest (89.89%) and lowest (87.05%) dry matter content, respectively. Mean crude protein was 7.74%; UG2-9-01 and UG2-11-03 had the highest (8.25%) and lowest (7.29%) crude protein respectively. UG1-5-38 and UG1-5-22 had the highest (8.12%)

**Corresponding author: Email: marynjei@yahoo.com, maryabua44@gmail.com;*

and lowest (6.41%) crude fibre content respectively. The oleoresin content ranged from (6.25%) in UG2-9-01 to (9.09%) in UG1-11-07. UG1-5-04 and UG1-5-22 had the highest (2.88%) and lowest (2.22%) ash content respectively. UG2-9-01 had the highest carbohydrate content of (65.10%). While UG1-5-52 had the lowest (61.27%) The result showed that the ginger lines used in this study had high mean carbohydrate (62.85%) and protein (7.74%) contents as such can be used as supplementary sources of these nutrients for human and livestock. UG1-7-24, UG1-11-07 and UG1-5-18 with high oleoresin contents of 9.11%, 9.09% and 9.05% respectively are recommended to ginger breeders as useful genotypes for improving other ginger lines through micropropagation techniques especially when breeding for oleoresin quality, which is an important quality of ginger. In conclusion, further evaluation and testing of these ginger lines is recommended.

Keywords: Ginger; oleoresin; induced mutant; micropropagation; landraces.

1. INTRODUCTION

Ginger, *Zingiber officinale* is a spice; and like some other spices, such as mustard, nutmeg, garlic, coriander, locust bean, cloves, cinnamon, pepper, garlic, onion, curry, and thyme Odebunmi et al. [1] has found it uses in flavour, food colouring, food preservations and medicines. Ginger has been used as a medicine and herbal since ancient times and also as an important cooking spice throughout the world Nour and Yap [2], Mohamad et al. [3].

Ginger is one of the fastest growing spices in the world market and Nigeria ginger is one of the best in the world. Nigeria ginger is sought after, because of its aroma, pungency and high oleoresin content Onwuka et al. [4], Manisha et al. [5]. Globally, the demand for ginger is increasing yearly due to its diverse utilization FAO, [6], FAOSTAT, [7]. The rhizomes are not only used as dietary spice, but also as herbal remedy in treating many diseases affecting humanity. These diseases include high cholesterol level, cancer, diabetics, hepatitis, arthritis, cramps, rheumatism, sprains, sore throats and hypertension Ali et al. [8], Manisha et al. [5].

In years to come, the demand for ginger may even exceed the supply. The solution to this challenge, is the cultivation of stable and high yielding genotypes with high nutritional qualities to meet with the demand. The high demand for the crop in the International market makes it an important export crop from Nigeria, and thus serves as source of foreign exchange which will help to boost the economy.

Ginger is employed in the preparation of numerous products including processed meat, sausages, sauces, vinegar, mustard, pickles, chutneys, preserves, salad dressing, biscuits, cookies, cakes, confectioneries and beverages Eleazu et al. [9]. Altman and Marcussen [10], Abubakar et al. [11] reported that ginger being a traditional drug since pre-historic times is used in treating various diseases like stomach upset, nausea, diarrhoea, arthritis and menstrual pains. Ginger is used as a flavouring agent in foods and beverages and as a fragrance in soaps and cosmetics Alam [12], Manisha et al. [5]. Other constituents that determines the quality of ginger apart from the oleoresin are, fats, proteins, carbohydrates, vitamins (C and B) and minerals Onwuka et al. [4]. USDA [13], Abubakar et al. [11] also reported that the rhizome of ginger is a rich source of vitamin B, C and E and mineral elements like calcium, manganese, zinc, iron, magnesium, phosphorous, potassium and sodium.

Nutritional quality of edible plants and vegetables plays an important role in determining their significance in nutrition Pandey et al. [14]. Nutritional quality of a substance is made up of several classes of nutrients in the samples such as carbohydrates, proteins, fat and oils, crude fibre, ash and moisture as well as calorie value calculated from values of carbohydrate. These nutrients are essential for the physiological functions of the human body. Such nutrients and biochemicals like carbohydrates, fats and proteins play important roles in satisfying human needs for energy and life processes Adnan et al. [15], Samidha et al. [16]. World Health Organization (WHO) has emphasized on the necessity of determining the nutritional quality of herbal plants, and this must pass through standard procedures Niranjan and Kanaki [17], Samidha et al. [16]. Knowledge of the variations in the different classes of nutrient present in the rhizome of these mutant ginger lines is needed for the identification of genotypes with desirable nutritional characters which will not only find use of its quality as a food adjunct or food accessory

and for curative purposes but also as a source of germplasm in breeding programmes aimed at developing ginger varieties with improved biochemical and nutritional traits. Therefore, the objective of this research was to determine the variations in nutritional qualities of 15 mutant lines and two landraces of ginger.

2. MATERIALS AND METHODS

The seventeen ginger genotypes were planted in the Teaching and Research Farm, Department of Crop Science, Faculty of Agriculture, Forestry and Wildlife Resources Management, University of Calabar, Calabar, Nigeria. Calabar is located in the South Eastern zone of Nigeria with latitude (4.9757^{o} N, and longitude 8.3417^{o}E) and about 39 m above sea level and has a bimodal annual rainfall distribution that ranges from 3,000 mm to 3,500 with a mean annual temperature range of 27ºC to 35ºC and relative humidity between 75-85%. Seventeen ginger genotypes consisting of fifteen (15) mutant lines (UG1-11-07, UG1-13-02, UG1-2-35, UG1-5-04, UG1,-5-18, UG1-5-22, UG1-5-31, UG1-5-35, UG1-5-38, UG1-5-48, UG1-5-49, UG1-5-52, UG1-7-24, UG2-11-03, UG2-9-01) and two landraces (UG1 and UG2) were sourced from National Root Crop Research Institute (NRCRI), Umudike, Abia State , Nigeria. The fifteen mutant lines were derived from the existing landraces UG1 and UG2 by exposing them to different doses of gamma rays irradiation [18]. The mutant lines derived from UG1 were exposed to 2GY, 5GY, 7GY, 11GY and 13GY doses of gamma-ray to give the following mutant lines; UG1-2-35, UG1-5-04 , UG1-5-18, UG1-5-22, UG1-5-31, UG1-5-35, UG1-5-38, UG1-5-48, UG1-5-49, UG1-5-52, UG1-7-24, UG1-11-07, UG1-13-02 [18]. The mutant lines derived from UG2 were exposed to 9GY and 11GY doses of gamma-ray to give the following mutant lines; UG2-9-01 and UG2-11-03. Iwo et al. [18].

Table 1 showing how the names of the mutant lines were derived is given below.

The ginger genotypes were raised in the field using the Randomized Complete Block Design in three replications. Each experimental unit measured 1 m x 2 m (2 m^2) with 0.5 m alley. The ginger setts or rhizomes were planted in rows with inter and intra row spacing of 50 cm.

2.1 Nutritional Analysis

Freshly harvested rhizomes of the 17 ginger genotypes (15 mutant lines) and two landraces were packaged, appropriately labelled and taken to the Biochemistry laboratory at the National Root Crop Research Institute (NRCRI), Umudike for analysis of their nutritional constituent. The nutritional constituents of the samples were determined using the Association of Official Analytical Chemists [19] official methods. The Ash content, oleoresin content, crude protein, moisture content, crude fibre, carbohydrate and dry matter content were determined as follows; Moisture content was determined by accurately weighing 5 g of fresh samples into a dried and weighed porcelain crucible. It was then oven dried at 70ºC for 24 hours. The porcelain crucible was removed and transferred into a desiccator for cooling after which it was weighed.

Table 1. Parent materials and their mutant lines

S/N	Wild types or landraces	Doses of gamma rays	Mutant lines derived
35	UG1	2GY	UG1-2-35
04		5GY	UG1-5-04
18		5GY	UG1-5-18
22		5GY	UG1-5-22
31		5GY	UG1-5-31
35		5GY	UG1-5-35
38		5GY	UG1-5-38
48		5GY	UG1-5-48
49		5GY	UG1-5-49
52		5GY	UG1-5-52
24		7GY	UG1-7-24
07		11GY	UG1-11-07
02		13GY	UG1-13-02
01	UG2	9GY	UG2-9-01
03		11GY	UG2-11-03

The percentage moisture content was calculated as follows:

$$\text{Moisture (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1}$$

where,

W_1 = Initial weight of empty crucible
W_2 = Weight of crucible + Sample before drying
W_3 = Weight of crucible + Sample after drying

Dry Matter contents of the samples were determined using the formula;

Dry matter (%) =100 - Percentage moisture content. The Kjedahl method was used to determine the total protein. 0.5 g of the sample was weighed into a Kjedahl flask8 to 10 cm^3 of concentrated H_2SO_4 were added and then digested in a fume cupboard until the solution became colourless. Distillation was carried out with about 10 cm^3 of 40% NaOH solution. The condenser tip was dipped into a conical flask containing 5 cm^3 of 4% boric acid in a mixed indicator till the boric acid solution turned green. Titration was done in the receiver flask with 0.01 M HCl until the solution turned red AOAC [19]. The ash content was determined by the incineration of 10.0 g of the samples placed in a muffle furnace maintained at 550º C for 5 hours. Crude fibre was, obtained by digesting 2.0 g of the samples with H_2SO_4 and NaOH and then incinerating the residue in a muffle furnace maintained at 550ºC for 5 hours. The methods of Onwuka [20] were used to determine the oleoresin content; 10 g of each of the fresh ginger rhizomes was washed properly with distilled water, sliced into chips of approximately 0.5 cm in diameter and dried in an oven at a temperature of 70ºC for 8 hours to a constant weight. About 5 g of the dried samples (W1) were mashed with 100 mls of acetone and the mixture was left overnight. It was later filtered (Whatman No. 1 filter paper) into a pre-weighed empty beaker (W2) and the acetone evaporated on a water bath at 65ºC, cooled and the whole setup was re-weighed (W3). The percentage oleoresin contents of the samples was determined by weight difference as follows;

Percentage oleoresin (dry weight) =

$$\frac{W_3 - W_2}{W_1} \times \frac{100}{1}$$

W_3 = Weight of beaker + oleoresin
W_2 = Weight of empty beaker
W_1 = Weight of sample taken

The carbohydrate content was calculated using the following formula proposed by Mathew et al. 2014 [21] ; Carbohydrate (%) = 100 - (% Protein + % moisture + % Ash + % crude fibre + % dry matter + % oleoresin content.

3. RESULTS

The nutritional qualities of seventeen ginger lines are shown in Table 2. The ginger lines varied significantly across all the nutritional attributes evaluated (P<0.01). The mean moisture content was 11.60% and ranged from 10.13% in UG1 to 12.95% in UG2 while dry matter content which had a mean of 88.89% was highest in UG1 (89.89%) and lowest in UG2 (87.05%). Crude protein ranged from 7.29-8.25% with a mean of 7.74%. UG2-9-01 had the highest protein content (8.25%) followed by UG2 (8.13%) while the lowest value for crude protein was observed in UG2-11-03 (7.29%). The mean crude fibre content was 7.38%. The highest value was recorded in UG1-5-38 (8.12%) while the lowest was in UG1-5-22 (6.41%). The oleoresin contents ranged from 6.25% in UG2-9-01 to 9.11% in UG1-7-24. Mean oleoresin content was 8.04%. The oleoresin contents of UG1-11-07 (9.09%) and UG1-5-18 (9.05%) were also relatively high.

Ash content varied from 2.22% in UG1-5-22 to 2.88% in UG1-5-04 and had a mean of 2.40%. Carbohydrate content ranged from 60.77% to 65.10% with a mean of 62.85%. UG2-9-01 (65.10%), UG2-11-03 (64.52%), UG1-5-04 (64.44%) and UG1 (64.40%) had the highest carbohydrate contents while UG2 (60.77%) and UG1-5-52 (61.27%) had the lowest.

4. DISCUSSION

The result from the proximate composition showed that the ginger lines differed significantly from each other in their nutritional qualities. The very high significant differences observed, is an indication that considerable genetic variations exist among the ginger lines in their nutritional qualities. This suggest the possibility of improvement of any of this nutritional quality through breeding programmes. The moisture content observed in the ginger lines were generally low with UG1 having the lowest while UG2 had the highest. The mean moisture content recorded in this study was similar to that reported by Eleazu et al. [9]. Moisture in food

Table 2. Nutritional quality evaluation of seventeen ginger genotypes

Genotype	Moisture Content (%)	Dry Matter (%)	Crude Protein (%)	Crude Fibre (%)	Oleoresin Content (%)	Ash Content (%)	Carbo-Hydrate (%)
UG1	10.13^{n}	89.89^{a}	7.38^{l}	7.40^{c}	8.28^{g}	2.42^{d}	64.40^{c}
UG1-11-07	10.86^{l}	89.14^{c}	7.74^{f}	7.18^{ef}	9.09^{a}	2.41^{d}	62.73^{i}
UG1-13-02	12.04^{e}	87.96^{i}	7.81^{e}	8.01^{b}	8.48^{f}	2.38^{ef}	61.29^{n}
UG1-2-35	11.24^{i}	88.76^{e}	8.05^{c}	7.27^{d}	8.59^{e}	2.34^{gh}	62.53^{j}
UG1-5-04	11.82^{f}	88.19^{h}	7.45^{k}	7.01^{h}	6.42^{k}	2.88^{a}	64.44^{c}
UG1-5-18	11.08^{k}	88.93^{d}	7.61^{h}	8.03^{b}	9.05^{b}	2.37^{ef}	61.87^{l}
UG1-5-22	11.51^{g}	88.50^{g}	7.51^{j}	6.41^{j}	8.64^{e}	2.22^{j}	63.72^{d}
UG1-5-31	12.12^{d}	87.89^{j}	7.48^{j}	7.05^{g}	8.12^{g}	2.39^{de}	62.84^{h}
UG1-5-35	12.48^{b}	87.52^{l}	7.64^{h}	8.02^{b}	6.52^{j}	2.28^{i}	63.08^{f}
UG1-5-38	11.18^{j}	88.82^{e}	7.57^{i}	8.12^{a}	8.68^{d}	2.31^{hi}	62.15^{k}
UG1-5-48	11.38^{h}	88.67^{f}	8.04^{c}	7.17^{f}	7.99^{h}	2.47^{c}	63.02^{g}
UG1-5-49	10.77^{m}	89.23^{b}	8.11^{b}	6.95^{i}	8.71^{d}	2.28^{i}	63.19^{e}
UG1-5-52	12.45^{b}	87.57^{l}	7.85^{d}	7.30^{d}	8.84^{c}	2.32^{h}	61.27^{n}
UG1-7-24	12.15^{d}	87.85^{j}	7.67^{g}	7.21^{e}	9.11^{a}	2.35^{fg}	61.52^{m}
UG2	12.95^{a}	87.05^{m}	8.13^{b}	8.02^{b}	7.65^{i}	2.49^{c}	60.77^{o}
UG2-11-03	12.35^{c}	87.65^{k}	7.29^{m}	6.96^{i}	6.31^{k}	2.58^{b}	64.52^{b}
UG2-9-01	10.82^{lm}	89.19^{bc}	8.25^{a}	7.27^{d}	6.25^{l}	2.32^{h}	65.10^{a}
Mean*	**11.60**	**88.89**	**7.74**	**7.38**	**8.04**	**2.40**	**62.85**

**Means with the same letter of the alphabet were not significantly different at 5% probability level using Duncan Multiple Range Test*

determines the rate of food absorption and assimilation within the body. It also determines the keeping quality of food. Low moisture content is an indication of good shelf life characteristics and minimal deterioration from microbes. The reduced moisture content observed in the ginger lines is an indication that their shelf life would be prolonged and that deterioration due to microbial contamination would be limited Dashak et al. 2001 [22]. Dry matter on the other hand was highest in UG1 and lowest in UG2. Dry matter contents of all the ginger lines evaluated were generally high. High dry matter content relates to good cooking quality and extended storage lives of the rhizomes. The crude protein contents of all the ginger lines evaluated were moderate but varied significantly between 8.25% in UG2-9-01 and 7.29% in UG2-11-03. These values are similar to the observations of Shahid and Hussein [23]. However, the values were much lower than the protein content values (17.44-20.23%) reported by Eleazu et al. [9] for some mutant ginger lines. The protein contents of the ginger lines indicate that their intake can contribute to the formation of hormones which controls a variety of body functions such as growth, repairs and maintenance of body. Crude fibre was highest in UG1-5-38 and lowest in UG1-5-22. Crude fibre refers to the plant materials that is indigestible. The low crude fibre in UG1-5-22, UG1-5-49 and UG2-11-03 posed no threat since ginger is usually consumed in addition to other foods. Hence, their low fibre contents serve as a boost to the total dietary fibre of the dishes in which they are added to. Crude fibre reduces blood cholesterol level in humans, prevents cancer, reduces the risk of developing diabetes and hypertension Yellavila et al. [24]. The oleoresin contents ranged from 6.25% in UG2-9-01 to 9.11% in UG17-24. This disagrees with the findings of Mohammed and Lakshmi [25], who reported that the oleoresin contents of ginger ranged from 1-4%. This variation could be attributed to varietal differences in the mutant lines. The oleoresin in ginger is essential and has been credited for the treatment of fracture, rheumatism, bruises, hangovers, cold, flu, catarrh, congestion, cough, sores, sore throat, diarrhoea, cramps, fever, anti-diabetic, antibacterial and antifungal properties in addition to very high antioxidant potential Yogeshwer and Madhulika [26]. The high oleoresin content observed in the ginger lines used in this study indicates that these ginger lines could have wide utility in the food, pharmaceutical and agricultural industries. Ash content varied from 2.22% in UG1-5-22 to 2.88% in UG1-5-04 and had a mean of 2.40%. The ash content of a biological material is an analytical term which refers to the inorganic residue that remains after the organic matter has been burnt away. It is an indication of the total inorganic mineral contents in the food

sample. Ene-obong [27], Sanam et al. [28]. The importance of ash content is that, it gives an idea of the total mineral content present in the sample while the organic matter gives an estimate of protein, lipid (fats), carbohydrate and nucleic acid content of the sample Onwuka [20]. The ash contents of the ginger lines were low compared to the report of Eleazu et al. [9]. Low ash is usually an indication of low inorganic mineral content Oloyede [29]. The carbohydrate fractions of all the 17 ginger lines were high, this was expected as rhizomes are the storage organ for carbohydrates. Carbohydrate content varied significantly between 60.77% in UG2 to 65.130% in UG2-9-01 with a mean of 62.85%. Carbohydrates play several vital roles in living organisms. They can be oxidized to yield energy, their polymers act as energy storage molecules and their derivatives are found in a number of biological molecules including coenzymes and the nucleic acids Hasan et al. [30]. The high carbohydrate fractions and moderate protein contents observed among the ginger genotypes consequently implies their importance as supplementary sources of these nutritive elements in diet for humans and livestock. Mohanta et al. [31] reported that diet is nutritionally satisfactory if it contains high caloric value and a sufficient amount of proteins.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

This research was carried out to evaluate the variation in the nutritional qualities of 17 ginger lines, The result showed that, the ginger lines used in this study had significant variations in their nutritional qualities. The ginger lines were generally high in their carbohydrate (62.85%) and protein (7.74%) contents. They can therefore serve as supplementary sources of these nutrients in diet for humans and livestock. The oleoresin contents of the ginger lines were also high (8.04%) Ginger varieties are usually rated to be of very high market quality based on their oleoresin contents. UG1-7-24, UG1-11-07 and UG1-5-18 had significantly the highest oleoresin contents and therefore, these lines can be used to improve the other ginger lines for essential oils and oleoresin. Further evaluation and testing of the nutritional qualities of these ginger lines is recommended.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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