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EFFECT OF GAMMA IRRADIATION ON THE DECAY OF COCOYAM (*COLOCASIA ESCULENTA)* CULTIVATED IN NIGERIA

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ABSTRACT

Cocoyam is a staple food consumed by different ethnic groups in Nigeria. One of the species of cocoyam cultivated in Nigeria is *Colocasia esculenta* (NCe 001 and NCe 011). Healthy, freshly harvested corms cultivated in Nigeria were sorted and weighed; each weighed 70 g. The sorted corms were divided into six equal groups of 7 kg for each variety. One group was not irradiated and served as the control; the remaining five groups were irradiated with gamma rays at 20 Gy, 40 Gy, 80 Gy, 120 Gy, and 150 Gy, respectively. An alanine dosimeter was used to verify the doses. The irradiated corms were stored for 28 weeks under ambient conditions and evaluated periodically for decay. Response Surface Methodology (RSM) was used for the experimental design. Three independent variables — dose, storage period, and variety — were examined in relation to the dependent response of decay. Statistical analysis using ANOVA showed significant difference ($p \leq 0.05$) between control and irradiated samples. The regression model and standard error values indicated a model that fits perfectly and has good predictive capability. The result also showed that, as the irradiation dose increased, the decay values decreased across the varieties. The percentage decay in NCe 001 decreased from 92% (control) to 56% (150 Gy), and for NCe 011, it decreased from 98% (control) to 47% (150 Gy). Gamma irradiation can therefore be used to minimize decay in *Colocasia esculenta* cultivated in Nigeria.

Keywords: Gamma irradiation, Dose, Storage time, Decay, Cocoyam, Corms

1.0 INTRODUCTION

Cocoyam (*Colocasia esculenta)* is a member of the family Araceae, which are herbaceous perennial plants that are widely grown for their corms. Postharvest conditions for harvested cocoyam are essential FAOSTAT (2022). Proper postharvest conditions are a challenge faced by cocoyam growers and marketers in Nigeria (Alabi *et al.,* 2019). Harvested corms have a shorter shelf life when improperly stored (Nwachukwu *et al.,* 2024). Incidences of an increase in postharvest loss are an issue of concern to African nations. In 2006, the African Ministerial Council on Science and Technology (AMCOST, 2006) reported a 20% more loss than the global average for agricultural products after harvest in Africa. More than 5 million people rely on these crops for food, feed, and income. Therefore, any loss due to postharvest operations deepens poverty and insecurity as income is lost (Otekunrin *et al.,* 2023).

Farmers have been known to use traditional methods for postharvest handling of their produce. However, these are less successful than more contemporary methods, such as irradiation to reduce decay in stored products. According to CGIAR (2020), farmers typically incur significant losses when their produce is stored using the conventional method, which usually does not last long. Technologies that meet modern extension and storage methods to minimise postharvest losses are important to ensure food security for individual households and the general populace (Kalu *et al.,* 2019). Jayaprakas & Harish (2022) noted that better storage techniques have been developed to minimise crop losses and lessen the reasons why cocoyam and yam tubers degrade after harvests. Muthoni & Shimelis (2023) reported that adopting

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modern technology would increase Africa's food security, income, and ability to manage food losses. This work used gamma irradiation a contemporary technology to improve on decay in stored cocoyam corms

2.0 METHODOLOGY

The cocoyam varieties used in this study were NCe 001 and NCe 011 of the *Colocasia esculenta* species. The corms were supplied by the Cocoyam Programme of the National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria. Forty-two kilogrammes (42kg) of fresh and healthy corms of the cocoyam varieties (NCe 001 and NCe 011) were sorted and weighed with each corm weighing 70 g. After sorting, each corm variety was divided into six equal groups of 7 kg (100 corms). For each variety, five groups were subjected to irradiation with five different doses of gamma rays (20Gy, 40Gy, 80Gy, 120Gy, and 150Gy) which served as the treatments, while the sixth group of each variety served as the control. The absorbed doses were confirmed using Alanine dosimeters (Bruker Biospin USA (Billerica MA), Lot T030901 with a coefficient of variation of 0.5%.

The Central composite design (CCD) of the response surface method (RSM) in the Minitab 17, 2013 version was used to develop a matrix for the experimental runs. Three independent variables were tested: dose, storage period and variety. Dependent parameter tested was decay. The method from a similar study by Madu *et al*., (2020) was adopted in determining the high and low points of the CCD. The matrix for the experimental runs is presented in Table 1.

Table 1: Design summary for irradiation and storage

Low	Constraint (variable) factors	High	Categorical (constant) factors
40 <	Dosage (Gy)	>120	Variety
6 <	Storage (Wks)	>24	

The irradiated corms were stored for 28 weeks to study the effect of dose, storage period and variety on the decay of the cocoyam spp. The corms were examined weekly for decay. The weights and records were taken for the number of decayed corms. The mean values were recorded. The decay loss was calculated as follows:

$$\%\ \text{decay loss} = \frac{\text{Initial weight of corms (Kg)} - \text{Weight of decayed corms (Kg)}}{\text{Initial weight of corms (Kg)}} \text{X } 100$$

3.0 RESULTS AND DISCUSSION

The effects of gamma irradiation on the storage decay of the two varieties of cocoyam stored for a period of 28 weeks from experimental matrix in Table 1 are presented in Table 2.

Table 2: Results obtained from the experiments on dose, storage and variety for decay in cocoyam corm after 28 weeks

Run	Dose (Gy)	Storage (weeks)	Variety	Decay (/100 corms)
1	150	6	NCe 011	22
2	20	15	NCe 011	25
3	80	15	NCe 001	61
4	40	15	NCe 001	52
5	20	15	NCe 001	50
6	80	28	NCe 011	36
7	80	15	NCe 011	71
8	120	15	NCe 011	53

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9	20	15	NCe 011	20
10	80	28	NCe 011	74
11	80	28	NCe 001	72
12	150	28	NCe 001	46
13	80	2	NCe 011	7
14	20	2	NCe 011	7

Run	Dose (Gy)	Storage (weeks)	Variety	Decay (/100 corms)
15	80	2	NCe 001	5
16	40	15	NCe 011	2
17	150	15	NCe 011	83
18	150	15	NCe 001	65
19	120	24	NCe 011	66
20	150	24	NCe 001	55
21	120	24	NCe 001	65
22	40	24	NCe 011	82
23	120	6	NCe 001	44
24	40	6	NCe 011	29
25	150	15	NCe 011	28
26	150	15	NCe 001	11
27	40	6	NCe 001	32
28	40	24	NCe 001	70
29	150	6	NCe 001	11
30	40	6	NCe 011	37
31	120	6	NCe 011	16
32	80	6	NCe 001	25
33	120	24	NCe 011	90
34	150	2	NCe 011	1
35	40	2	NCe 011	6
36	120	2	NCe 011	4

The mean values for the irradiated cocoyam corms that decayed for NCe 001 at the end of 28 weeks of storage are shown in Figure 1.

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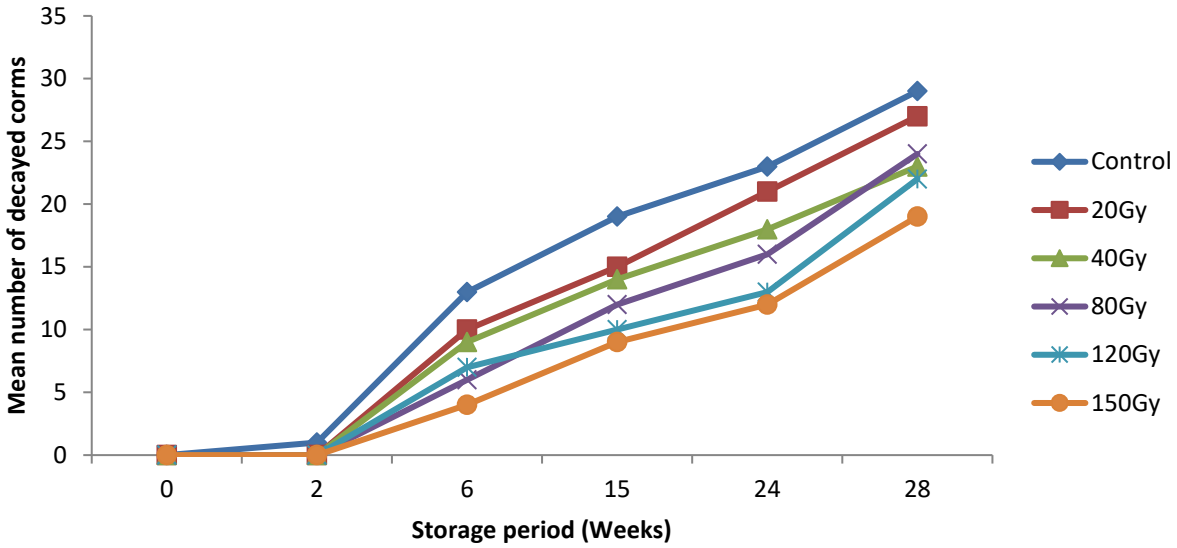

Figure 1: Mean values of decayed NCe 001 variety of cocoyam corms irradiated at different doses after 28 weeks

The result of the effect of dosage on decay from Figure 1 indicated that as the storage period increased, the mean number of decayed corms increased. It can be seen from Figure 1 that the control (unirradiated) samples deteriorated faster than the irradiated samples during storage. The result also showed that the sample irradiated at 150Gy had the least number of decay corms. Furthermore, the result revealed that as the dosage of gamma irradiation increased the rate of cocoyam decay during storage decreased. The percentage decay loss for the NCe 001 variety as observed in the study was 92%, 90%, 76%, 67%, 60%, and 56% for the control, 20Gy, 40Gy, 80Gy, 120Gy, and 150Gy respectively.

The result of the effect of dosage on decay for the irradiated cocoyam NCe 011 is illustrated in Figure 2.

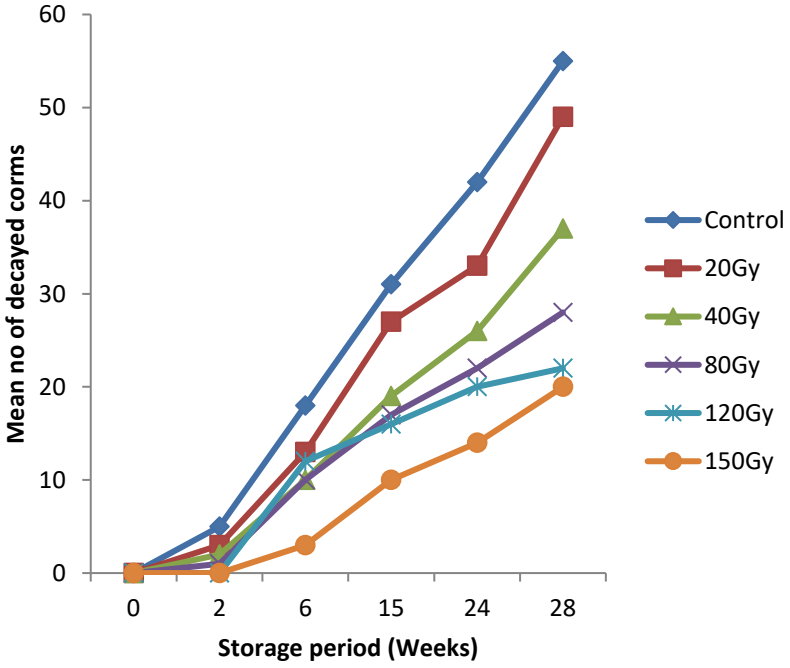

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Figure 2: Mean values of decayed NCe 011 variety of cocoyam corms irradiated at different doses after 28 weeks

The result from Figure 2 indicated that as the storage period increased the mean number of decayed corms increased. The control (unirradiated) samples from Figure 2 had more decayed corms than the irradiated samples during storage. The result also showed that the sample irradiated at 150Gy had the least number of decayed corms and that as the dosage of gamma irradiation increased, the rate of cocoyam decay during storage decreased. This similar trend has been established for NCe 001. The percentage decay loss for the NCe 011 variety was 98%, 88%, 77%, 65%, 56%, and 47% for the control, 20Gy, 40Gy, 80Gy, 120Gy, and 150Gy respectively.

Table 3 presents the statistical Analysis of Variance (ANOVA) of data obtained from the results using decay as the dependent variable. The significant difference model terms were identified at p≤ 0.05. Table 3 indicates that the control samples were significantly different from irradiated samples at p≤ 0.05 as represented by the model term. Table 3 also indicates that the interaction of dosage and storage (0.421), dosage and variety (0.233) as well as storage and variety (0.306) had no significant difference at p≤ 0.05.

Table 3: Analysis of Variance for Decay

Source	DF	SS	MS	F-Value	P-Value
Model	14	24482.8	1748.77	30.42	0.000*
Linear	5	16594.8	3318.96	57.73	0.000*
D	1	530.3	530.30	9.22	0.688**
ST	1	7072.6	7072.57	123.02	0.000*
V	3	9219.0	3073.01	53.45	0.000*
Square	2	263.9	131.94	2.30	0.161**
D*D	1	86.4	86.40	1.50	0.062**
ST*ST	1	263.4	263.37	4.58	0.146**
2-Way Interaction	7	5191.9	741.71	12.90	0.298**
D*ST	1	39.1	39.06	0.68	0.421**
D*V	3	627.3	209.11	3.64	0.233**
ST*V	3	4512.8	1504.27	26.17	0.306**
Error	28	1034.8	36.96		
Total	67	2517.6			
R^2	0.7962				
S	3.0862				

D = Dose (Gy); ST = Storage (weeks); V= Variety; R^2 = Coefficient of determination; S = Standard error of the regression; *significant difference ($p < 0.05$); **no significant difference ($p < 0.05$); DF (Degree of Freedom) = n – 1 (n = sample size); SS = Sum of Squares; MS (Mean of Squares) = SS ÷ DF.

The coefficient of determination (R^2) value of 0.7962 from Table 3 was relatively high and within the range reported by Madu *et al*. (2020) and Olorunsogo *et al.* (2023). Okonkwo (2014) further reported that a large value of R^2 does not principally suggest that the regression model equation is a good one because it will rise when a variable is added even though the new variable is of consequence or otherwise. Granato *et al.* (2010) recommended that standard error of the regression (S) could be used as another calibration tool as it is capable of overcoming the insensitivity of R^2. Granato *et al.* (2010) further noted that the higher value of S > 10 invalidates the adequacy of a model. The value of R^2 (0.7962) obtained was high and close to the threshold value of 1, and S=3.0862 < 10. These all indicated that

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the model sufficiently fitted well and thus, might forecast the effects of the independent variables on the decay up to nearly 80%. The finding of this study is in agreement with the works of Hussain *et al.* (2016), Alghifari *et al.* (2023), and Asare & Darfour (2024).

The Quadratic regression model equations developed to predict the independent variables are presented as equations 4.1 – 4.4.

$$NCe\ 011 = -18.97 + 0.352\ D + 7.10\ ST - 0.000993\ D^2 - 0.1731\ ST^2 + 0.00651\ D*ST \quad (1)$$

$$NCe\ 001 = -6.50 + 0.174\ D + 7.40\ ST - 0.000993\ D^2 - 0.1731\ ST^2 + 0.00651\ D*ST \quad (2)$$

Table 4 presents the regression coefficients obtained from the results using decay as the dependent variable after 28 weeks of storage

Table 4: Regression Coefficients for decay

Term	Effect	Coeff.	SE Coeff.	t-value	p-value
Constant		31.56	3.66	8.62	0.000*
D	13.52	6.76	2.22	3.04	0.007*
ST	43.73	21.87	1.97	11.09	0.000 *
V					
NCe 011	29.81	14.91	2.32	6.42	0.000*
NCe 001	32.37	16.19	2.25	7.19	0.000*
D*D	-11.18	-5.59	4.56	-1.23	0.436**
ST*ST	-16.97	-8.48	3.96	-2.14	0.046*
D*ST	6.84	3.42	4.15	0.82	0.421**
D*V					
NCe 011	23.83	11.91	3.70	3.22	0.005*
NCe 001	-2.86	-1.43	3.70	-0.39	0.704**
ST*V					
NCe 011	28.51	14.25	3.23	4.42	0.000*
NCe 001	32.81	16.41	3.03	5.41	0.000*

D = Dose (Gy); ST = Storage (weeks); V= Variety; *significant difference ($p < 0.05$); **no significant difference ($p < 0.05$).

A positive regression coefficient indicates that as the mean values of the independent variable increased, the mean of the dependent variable also tends to increase. A negative coefficient suggests that as the independent variable increased, the dependent variable tends to decrease. Regression coefficients having t-values beyond -2 and +2 as well as p-values ≤ 0.005 are statistically significant.

The results from Table 4 indicated that dosage had the greatest effect on NCe 011(23.83) while storage had the least effect on NXs 001 (-15.79). The effect of dosage and storage had no significant difference (0.421) at p≤ 0.05. However, dose had a significant difference on NCe 011 (0.005) at p≤ 0.05 and storage had a significant difference on all the varieties at p≤ 0.05.

The mean values for the overall effect of dosage of irradiation on decay of the two varieties of cocoyam corms are shown in Figure 3.

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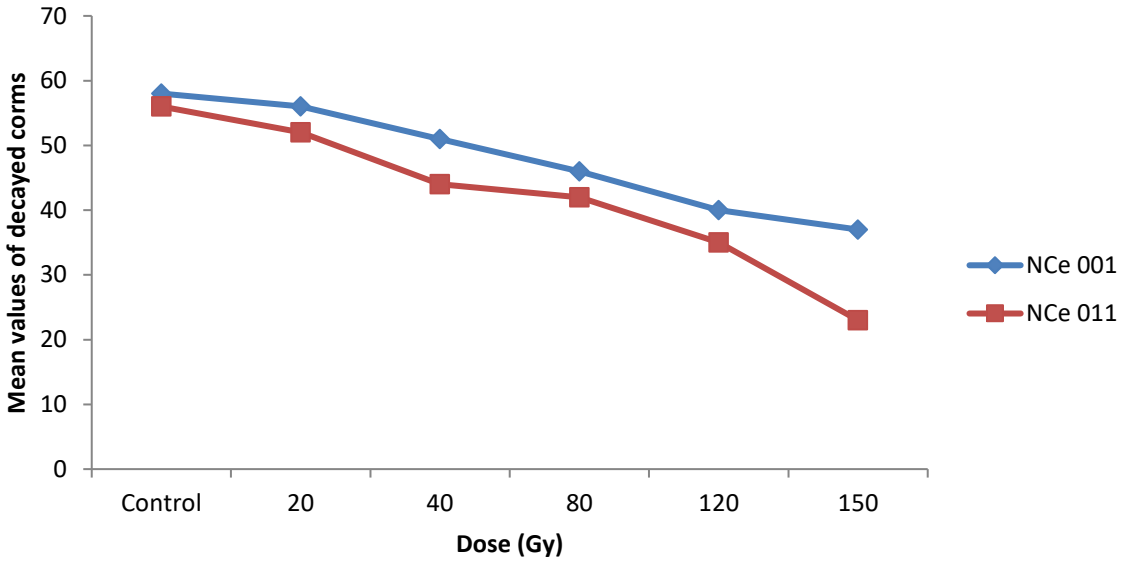

Figure 3: Mean values of decay of the two varieties of cocoyam corms irradiated at different doses

NCe 001 variety decayed faster than NCe 011 variety from the result in Figure 3. The control samples from Figure 3 had higher number of decayed corms than the irradiated samples during storage, also showed that the number of decayed corms decreased as the dosage of irradiation increased.

Irradiation according to Singh and Kaur (2016), can reduce decay in traditional storage system from 10-12 % to 2.8%. Asare & Darfour (2024)noted that irradiation prevents condensation of transpired vapour on tuber surface thus preventing excessively wet condition within the storage area this may have accounted for why the percentage of deterioration in irradiated samples is lowered as the dosage of irradiation increased. Low moisture assists in reducing the development of fungal diseases that normally thrive under humid and warm conditions% Cahyanti *et al.* (2022). Cahyanti *et al.* (2024) reported that noticeable decay in corms was because of microbial activity at temperatures slightly above room temperature. Elevation of temperature causes the starch in the corms to gelatinize Asare & Darfour (2024). These gelatinised starches serve as feed stock for microbes (Muthoni & Shimelis 2023).

4.0 CONCLUSION

Food products are legally irradiated in many countries and probably also exported to countries that do not permit the irradiation of any food to facilitate international trade and strengthening consumer confidence. Irradiation of cocoyam corms in the study demonstrated positive results. The control samples had a greater number of decayed corms than the irradiated samples during storage. The number of decayed corms decreased as the dosage of irradiation increased with the NXs 002 variety decaying faster than NXs 001 variety. Irradiation process can be used to minimise decay in cocoyam corms.

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