Effect of Doses and Storage Time on Acridity of Irradiated Cocoyam Corms

Abstract

Cocoyam is a stable food commonly eaten by the people of Eastern Nigeria. Its utilization as a raw material for food products is affected by its acridity content. The traditional method of processing cocoyam for consumption is by cooking which is time and energy consuming. Nigeria Colocasia esculenta spp (NCe 001 and NCe 011) and Xanthosoma sagittifolium spp (NXs 001 and NXs 002) were subjected to gamma irradiation of 20, 40, 80, 120 and 150Gy for one hour and stored. The controls samples and the stored irradiated samples were analysed to determine their acridity content. The effect of storage time on the acridity content of the irradiated cocoyam samples was studied. The main and interaction effects of storage time and dosage on acridity content were obtained statistically. The result of the study showed that there was a 50% reduction in the acridity content of the irradiated samples after 28 weeks of storage. A significant impact on the acridity content for all the varieties at above 80Gy was observed from the result of the study. There is limited information on the effect of gamma irradiation dose rate and storage period on the acridity in the four cocoyam varieties found in Nigeria. The main purpose of this study is to determine the effect of gamma irradiation dose rate and storage period on the acridity content of these four cocoyam varieties.

Key words: Acridity, Irradiation, Storage Time, Dose, Cocoyam

Introduction

Cocoyam (*Xanthosoma sagittifolium spp*. and *Colocasia esculenta spp.*), is a member of the *Araceae* family. They are one of the oldest crops grown for its edible corms and leaves (Alabi *et al.*, 2019). Some tropical root and tuber crops, to which cocoyam belongs constitute an under-exploited resource of developing countries. Ranking as the fourteenth most consumed vegetable worldwide; cocoyam leaves are widely grown in tropical and sub-tropical countries (Adeyanju*et al.*, 2019). Many of the developing world's poorest farmers and food insecure people are highly dependent on root and tuber crops as a contributing, if not the principal, source of food, nutrition, and cash income (Alabi *et al.*, 2019). About 60% of the world cocoyam production (5.7 million tonnes) is in Africa and most of the remaining 40% in Asia and the Pacific (Owusu-Darko *et al.*, 2014).

Cocoyam forms part of the diet, but to a lesser extent in Nigeria where it is locally known as *"Ede"* in parts of Igbo land. The principal component of these tropical root and tuber crops is starch, which is increasingly becoming an important raw material for the food and non-food industries worldwide. The current industrial demand for starch is being met by a restricted number of crops mainly corn, potato and wheat. Consequently, the world starch market is dominated by starches from these three crops (Owusu-Darko *et al.*, 2014). Despite being grown on a smaller scale in Nigeria, cocoyam can offer an opportunity as a new source of starch for the Nigerian industry if handled well.

Cocoyam consumption has been affected because of the presence of acridity factors. Acridity in cocoyam causes sharp irritation and burning sensation in the throat and mouth on ingestion

(Samaa, 2019). The acridity factor is one of the major problems encountered by those who consume cocoyam and this can be reduced by peeling, grating, soaking and fermentation operations during processing. Other methods of removing acridity include fermentation, baking or extraction with ethanol (Azene and Molla, 2017) and irradiation.

Food irradiation is a postharvest technology used to control insect infestation and the numbers of pathogenic or spoilage microorganisms. It also helps to arrest or reduce ripening in fresh fruits and vegetables; sprouting in tubers and germination that occurs in bulbs (Ravindran and Jaiswal 2019). During radiation processing changes occur in cells leading to the destruction of pest insects and microorganisms (Madu *et al* 2020). These radiations have the ability to remove electrons bonded in an atom and molecule with their high energy making them become electrically charged and are thus known as ionising radiations (Zanardi *et al.*, 2018). There are three types of ionising radiation sources authorised to be used during the process of food irradiation. These sources are namely $^{60}C_O$ gamma sources, electron beam generators, and X-ray generators (Madu *et al.*, 2020). Roots, tubers and Bulbs such as potatoes and onions have been recommended for irradiation. The European Union (EU) passed into law Directive 1999/2/EC which entered into force on March 10, 1999 recognizing the use of radiation processing in food. The process has been shown to be safe for human consumption. The US Food and Drug Administration (FDA) allows the use of irradiation as a means for improving food safety and extending the shelf life of certain foods, roots, tubers, corms and bulbs. Potatoes have been irradiated in Japan for over 26 years to prevent sprouting (Nabeshima *et al*., 2020).

Materials and methods

The four cocoyam varieties used in this study were NXs 001 and NXs 002 of the *Xanthosoma sagittifolium* species and cultivar; NCe 001 and NCe 011 of the *Colocasia esculenta* species and cultivar. The corms were supplied by the Cocoyam Programme of the National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria.

Forty-two kilogrammes (42kg) each of fresh and healthy corms of the four cocoyam varieties were sorted. The 42kg samples of corms were divided into six different groups, one group served as the control which was analysed immediately after harvest to determine the acridity content. The other five groups were packaged in polyethylene bags of 2 mm thickness and labelled accordingly. Each package containing 7kg of corms was treated with gamma irradiation for 1 hour using five different doses of 20Gy, 40Gy, 80Gy, 120Gy and 150Gy. The absorbed doses were confirmed using Alanine dosimeters (Bruker Biospin USA (Billerica MA), Lot T030901. The irradiated samples were stored and analysed for acridity. The rapid test method of Association of Official Analytical Chemists (AOAC)(2005) was used to determine the acridity content (%). The experimental results were replicated three times and the mean values were used. Statistical analysis of the experimental results was conducted for Analysis of variance and Regression coefficient.

Results and Discussions

The results for the effect of storage on the acridity content for the irradiated NCe 001 cocoyam corms are shown in Table 1.

Table 1: Acridity content (%) of irradiated cocoyam corms during storage

Storage Time (weeks)	Dose (Gy)					
	Control	20	40	80	120	150
NCe 001						
0	6.5	6.2	5.9	5.7	5.6	5.3
2	5.9	5.9	5.8	5.5	5.4	5.1
6	5.5	4.7	4.2	3.9	4.5	4.8
15	5.3	3.1	3.7	3.1	4.1	3.3
24	5.1	3.5	3.2	2.8	3.8	3.1
28	5.1	3.2	2.3	2.6	3.2	3.1
NCe 011						
0	7.4	7.1	6.8	6.5	6.3	6.0
2	5.9	5.8	5.6	5.4	5.3	5.1
6	5.7	4.7	4.4	3.7	5.1	4.9
15	5.5	3.0	3.5	3.1	3.5	3.3
24	5.3	3.1	3.0	3.1	3.3	3.1
28	5.1	3.2	3.2	3.5	3.1	3.1
NXs 001						
0	5.4	4.4	4.2	4.8	4.0	4.2
2	5.2	3.5	3.7	3.5	3.6	3.6
6	5.1	3.3	3.1	2.7	3.1	3.2
15	4.9	2.9	2.4	2.1	2.3	2.6
24	4.7	2.7	2.2	2.1	2.2	2.3
28	4.7	2.4	2.1	1.9	2.1	2.1
NXs 002						
0	4.2	3.6	3.2	3.4	3.0	3.2
2	4.1	2.8	2.9	2.7	2.6	2.8
6	3.9	2.5	2.3	2.1	2.3	2.7
15	3.8	1.8	1.7	1.7	1.8	2.6
24	3.7	1.6	1.6	1.5	1.5	2.4
28	3.6	1.7	1.5	1.5	1.4	2.1

Table 1 indicated that the acridity content of NCe 001 and NCe 011 decreased as the storage period increased. The control samples had higher acridity content than the irradiated corms. The results for the effect of storage on acridity contents for the irradiated NXs 001 and NXs 002 cocoyam corms as presented in Table 1 also indicated that the acridity content decreased as the storage period increased. The control samples also had higher acridity content than the irradiated corms. For all irradiated samples across the four varieties the 80Gy irradiated samples had the least mean acridity content. The results from Table 1 also indicate a 50% reduction in the acridity content of all the irradiated samples.

The results of the statistical analysis of variance for acridity contents of the four irradiated cocoyam corms are presented in Table 2.

Table 2: Analysis of variance for acridity content

Source	**DF**	**SS**	**MS**	**F-Value**	**P-Value**
Model	14	15.5957	1.1140	22.80	0.000*
Linear	5	13.8537	2.7707	56.71	0.000*
D	1	12.3692	12.3692	253.15	0.000*
ST	1	0.0090	0.0090	0.18	0.673**
V	3	1.4635	0.4878	9.98	0.000*
Square	2	0.1481	0.0740	1.52	0.247**
D*D	1	0.0456	0.0456	0.93	0.347**
ST*ST	1	0.0154	0.0154	0.32	0.581**
2-Way Interaction	7	1.1270	0.1610	3.29	0.019*
D*ST	1	0.0900	0.0900	1.84	0.191**
D*V	3	0.6643	0.2214	4.53	0.016*
ST*V	3	0.3708	0.1236	2.53	0.090**
Error	18	0.8795	0.0489		
Total	32	16.4752			
R^2	0.9466				
S	0.221045				

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 study from the results in Table 2 indicates that the irradiated and control samples showed significant differences at $p \leq 0.05$; this is represented by the model term. It also presents that the two-way interaction had no significant difference at $p \leq 0.05$ for the interaction between dosage and storage time (0.191), and for storage and variety (0.090) but had significant difference at $p \leq 0.05$ for the interaction between dosage and variety (0.016),

The regression coefficients for acridity contents for the four irradiated cocoyam corms are presented in Table 3.

Table 3: Regression Coefficients for acridity content

Term	**Effect**	**Coeff**	**SE Coeff**	**T-Value**	**P-Value**
Constant		3.951	0.107	37.02	0.000*
D	2.0641	1.0320	0.0649	15.91	0.000*
ST	-0.0493	-0.0246	0.0575	-0.43	0.673**
V					
NCe 011	-0.7205	-0.3602	0.0677	-5.32	0.000*
NCe 001	0.1636	0.0818	0.0657	1.25	0.229**
NXs 001	0.4070	0.2035	0.0677	3.01	0.008*
NXs 002	0.4073	0.2021	0.0679	3.01	0.008*
D*D	0.257	0.128	0.133	0.97	0.347**
ST*ST	-0.130	-0.065	0.116	-0.56	0.581**

D*ST	0.328	0.164	0.121	1.36	0.191**
D*V					
NCe 011	0.065	0.033	0.108	0.30	0.765**
NCe 001	-0.741	-0.370	0.108	-3.43	0.003*
NXs 001	0.516	0.258	0.108	2.39	0.028*
ST*V					
NCe 011	-0.4181	-0.2090	0.0941	-2.22	0.039*
NCe 001	0.0038	0.0019	0.0885	0.02	0.983**
NXs 001	0.4338	0.2169	0.0941	2.31	0.033*

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

Results obtained from Table 3 indicate that dosage had a positive effect on NCe 011 (0.065) and NXs 001 (0.516) and a negative effect on NCe 001 (-0.741). Storage had a negative effect on NCe 011 (-0.4181) and a positive effect on NCe 001 (0.0038) and NXs 001 (0.4338). The combined effect of dose and storage showed no significant difference (0.191) at $p\leq0.05$. The effect of dose on NCe 001 (0.003) and NXs 001 (0.028) as well as the effect of storage on NCe 011 (0.039) and NXs 001 (0.033) showed significant difference at $p\leq0.05$.

Cocoyam is a good base for food preparation for infants because of the high digestibility of its starch, reasonable content of calcium and phosphorus (for bone building), B-complex vitamins and provitamin A (Ihediohanma *et al.,* 2014). Infants in some developing countries are traditionally weaned solely on starch prepared from pre-cooked, wet-milled and wet-sieved corn (Mahmoud and El Anany, 2014). Forsido *et al.,* (2019) also reported that cocoyam starch can be incorporated in the development of weaning food which is easily digestible and accessible to low-income earners in developing countries. The major limiting factor in the utilisation of cocoyam corms is the presence of anti-nutritional factor known as acridity. The effects of this anti-nutrient usually include reduced feed intake, digestibility, nutrient utilisation, and weight gain (Ukom *et al.*, 2018). Acridity is associated to needle-like raphids of calcium oxalate crystals compounds (Rozali *et al.*, 2021). Its oxalate content is responsible for the perceived irritation when the corm is in-jested without treatment (Samaa, 2019). The oxalic acid which is heat labile can occur as a soluble or an insoluble acid (Achadu *et al.*, 2019). The result obtained from the study can be attributed to energy emitted during irradiation having an equivalent energy level comparable to that emitted by heating the cocoyam corm. The mean acridity content range of 1.7 – 7.7% obtained in this study for *Colocasia* and *Xanthosoma*spp falls within the range of values (1.8 – 8.2 %) reported by Acheampong *et al.* (2016), in their work with *Colocasia spp* subjected to cooking treatment. It is also in agreement with the values reported by Amadi *et al.* (2018) in their work with *Xanthosoma* spp subjected to ash solution treatment.

Conclusion

Cocoyam with its reported nutritional advantage over other tuber and root crops has its use being limited by its acridity content. The results obtained from the study indicate that there is a direct relationship between dosage and storage on the acridity factor. Irradiation of the cocoyam varieties above 70Gy and storage time of 13 weeks reduced the acridity factor by 50%.Starch from irradiated cocoyam corms therefore can be incorporated in the development and formulation of food and food products.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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