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Effect of Plant Maturity on the Antioxidant Profile of *Amaranthus cruentus* L. and *Celosia Argentea* L.

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ABSTRACT
Amaranthus cruentus L. and Celosia argentea L. were analyzed for antioxidant activities and antioxidant phenolic compounds at 3, 4, 5 and 6 weeks maturity. The results of the study showed that as A. cruentus matured from 3 weeks to 6 weeks after planting, antioxidant activities, total phenol and flavonoid concentrations increased. Antioxidant activities ranged from 40-74%, total phenol ranged between 2750-6330 mg/100 g while flavonoid was between 91-125 mg/100 g. Antioxidant activities, total phenol and flavonoid concentrations of C. argentea peaked at 5 weeks, after which there was reduction. Antioxidant activities was generally high in C. argentea (75-81%) while total phenol ranged between 9167 to 19344 mg/100 g. Antioxidant activities of C. argentea was higher than that of A. cruentus at 3 to 5 weeks of harvest but not significantly higher at 6 weeks. In terms of antioxidant profile, these vegetables are best consumed at 5-6 weeks of age.
Key words: *Antioxidant activities; flavonoid; plant maturity; total phenol; vegetables.*

INTRODUCTION

Amaranthus cruentus L. and *Celosia argentea* L. are among the green leafy vegetables commonly consumed in Nigeria, though *A. cruentus* is more popular. They belong to the family Amaranthaceae. Green leafy vegetables have been recognized as rich source of micronutrients (minerals and vitamins) and antioxidants [1]. Diets which contain an abundance of fruit and vegetables are protective against a variety of diseases, particularly cardiovascular diseases and epithelial (but not hormone-related) cancers [2]. The principal nutrients thought to provide the protection afforded by fruits and vegetables are the antioxidants [3] and dietary fibre i.e. non-starch polysaccharides [4].

The quality of vegetables can be influenced by various factors such as genotypic differences, pre-harvest conditions, cultural practices, stage of maturity, harvesting method and post-harvest handling procedures as well as the interactions among these factors [5, 6, 7]. According to Baranga [8], the nutrient quality of plant leaves generally declines with advancing maturity resulting in a decrease in protein levels and a concomitant increase in the amount of indigestible structural carbohydrates. Biologically active compounds have however been found to increase in plant leaves during the process of maturation depending on the different biosynthetic pathways and mechanisms of metabolic control [9, 10, 11, 12].

There are many documented studies on nutritional compositions of vegetables generally, however little or nothing is known about what happens to their bioactive compounds at different stages or periods of harvesting. This study therefore evaluated the influence of harvesting periods on the antioxidant activities and the concentrations of antioxidant phenolic compounds of *Amaranthus cruentus* and *Celosia argentea*.

MATERIAL AND METHODS

Field Study

Amaranthus cruetus and *Celosia argentea* were grown at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria during the late season in 2008. 6 m x 4 m land area was used and the planting replicated thrice. The four different stages of maturity used in the study were 3 weeks, 4 weeks, 5 weeks and 6 weeks of age. At the end of each stage, the edible portions of plant samples were

collected from the 3 replicates and composite samples formed. The collected samples were washed with distilled water, dried in the oven at 45^0C, made into fine powder and stored for antioxidant assay.

Laboratory Study

All the composite samples were analyzed in duplicate for antioxidant activities, total phenol, total flavonoid, anthocyanin and proanthocyanidin. Five grams each of the composite samples were extracted by cold extraction i.e. extraction not involving heat, for 24 hours using 80% methanol. The crude extract was obtained by evaporation of the methanol soluble extract to dryness. The antioxidant activities or hydrogen donating or radical scavenging of the extract was determined using the stable radical DPPH (2, 2-diphenyl-2-picrylhydrazyl hydrate) according to the method described by Brand-Williams [13]. DPPH reacts with an antioxidant compound which can donate hydrogen and it is reduced. The change in colour from deep violet to light yellow was measured spectrophotometrically at 517 nm. Total phenol content was determined by the method of Singleton and Rossi [14] using the Folin – Ciocalteau reagent in alkaline medium. Total flavonoid content was determined using $AlCl_3$ method as described by Lamaison and Carnet [15]. The proanthocyanidin content was determined using a modified method of Porter *et al.* [16] using the AlCl / Butan – 1-0l assay method. The total anthocyanin content of the test samples was determined using the pH differential method of Fuleki and Francis [17] as described by Guisti and Wrolstad [18].

Statistical Analysis

All analyzed data were subjected to combined analysis of variance SAS [19]. Means squares, where significantly different for plant maturity were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability. Regression analysis was used to compare the antioxidant activities of the vegetables evaluated.

RESULT

The antioxidant activities (%) and phenolic compounds of *Amaranthus cruentus* as affected by plant maturity at harvest is presented in Table 1. The antioxidant activities is relatively high and increased with plant maturity. The same trend was observed in total phenol. The total phenol content was highest at the 6th week of harvest (6328 mg/100 mg), while the phenol content was lowest at the 3rd week (2754 mg/100 g). The flavonoid content also has highest content at the 6th week (125 mg/100 g) while there was no significant difference between the flavonoid content at 4th and 5th week of harvest. The lowest content was found at the 3rd week. Anthocyanin content of *A. cruentus* decreased with increasing plant maturity. The highest anthocyanin content was found at the 3rd week of harvest (1.94 mg/100g) while it was lowest at the 6th week (0.17mg/100g). Proanthocyanidin content of *A. cruentus* was not affected by plant maturity. The content ranged from 0.07 to 0.13mg/100g across the harvesting period.

Table 2 presents the antioxidant profile of *Celosia argentea* as affected by plant maturity. Antioxidant activities of *C. argentea* was generally very high across the harvesting periods. This ranged from 75-81%, the highest concentration being found at the 5th week of harvest and the lowest at the 3rd week. The same trend was observed in the total phenol and flavonoid contents which increased with increasing plant maturity and peaked at the 5th week. The concentrations however declined at the 6th week of harvest. The total phenol and flavonoid concentrations ranged from 4857-19344 mg/100 g and 91-199 mg/100 g respectively with the lowest found at the 6th week. Anthocyanin and proanthocyanidin concentrations were similar and highest at 4th to 6th weeks of harvest. The concentrations ranged from 0.5-0.9 mg/100 g and 0.05-0.09 mg/100 g for anthocyanin and proanthocyanidin respectively.

Fig. 1 compares the antioxidant activities of *Amaranthus cruentus* and *Celosia argentea*. At 3 to 5 weeks of harvest the antioxidant activities of *Celosia argentea* was much higher than that of *Amaranthus cruentus*. However, the antioxidant activities of the vegetables did not differ significantly at the 6th week. The response of *A. cruentus* fitted into linear equation with R^2 of 0.885 while that of *C. argentea* is 0.016. This means that the 88.5% variation in the antioxidant activities of *A. cruentus* can be attributed to plant maturity, while it was only 1.6% for *C. argentea*. This implies that the period of harvesting is more critical to *A. cruentus* compared to *C. argentea* in terms of their antioxidant activities.

Table 1: Antioxidant profile of *Amaranthus cruentus* as affected by harvesting period (Dry weight basis).

WEEK OF HARVEST	Antioxidant activities (%)	Phenol (mg/100 g)	Flavonoid (mg/100 g)	Anthocyanin (mg/100 g)	Proanthocyanidin (mg/100 g)
3	40.68d	2754d	90.9c	1.94a	0.07a
4	44.33c	3532c	108b	1.54b	0.13a
5	53.29b	5405b	108b	0.50c	0.12a
6	74.41a	6328a	125a	0.17d	0.13a

Means with the same letter in each column are not significantly different at 5% level of Probability using Duncan's multiple range test.

Table 2: Antioxidant activities of *Celosia argentea* as affected by harvesting period (Dry weight basis).

WEEK OF HARVEST	Antioxidant activities (%)	Phenol (mg/100g)	Flavonoid (mg/100g)	Anthocyanin (mg/100g)	Proanthocyanidin (mg/100g)
3	75.05c	9167c	125.0c	0.48c	0.05c
4	77.79b	18968b	159.1b	0.85a	0.09a
5	81.44a	19344a	198.9a	0.89a	0.09a
6	74.86d	4857d	90.9d	0.90a	0.09a

Means with the same letter in each column are not significantly different at 5% level of Probability using Duncan's multiple range test.

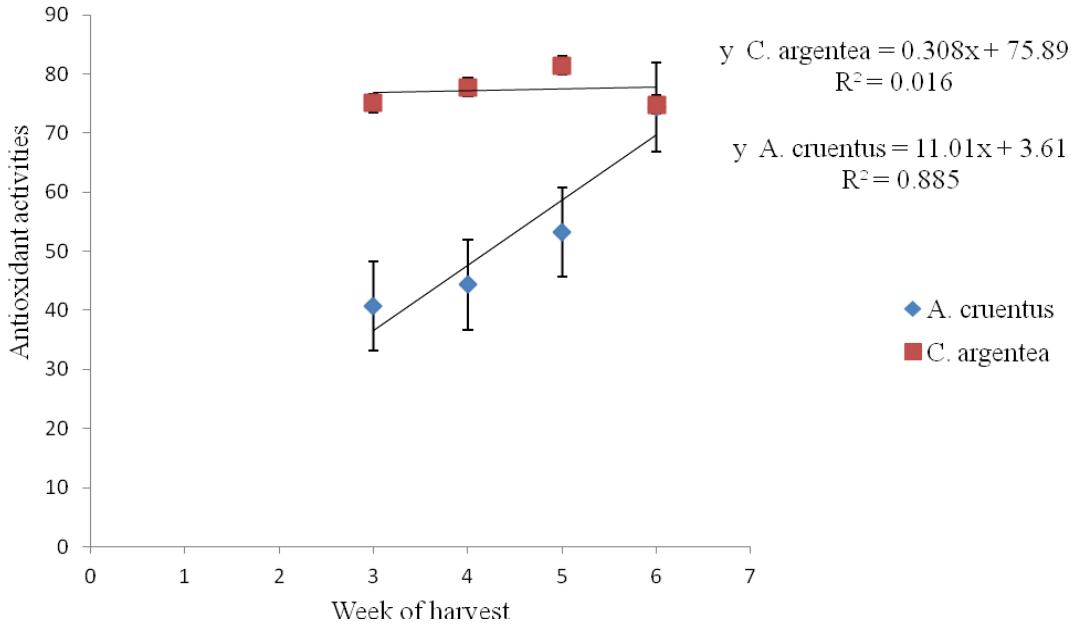

Fig. 1. Antioxidant activities of *Amaranthus cruentus* and *Celosia argentea*

DISCUSSION

The gross composition of plant tissues can vary quite considerably during the growth. Since harvesting fruits and vegetables at their correct stage of maturity is critical in order to produce a highly acceptable product for immediate consumption and for processing, the importance of the thorough knowledge of these changes cannot be overemphasized. As a plant grows older and larger, the growth rate slows; the branching structure becomes more complex, the number of terminal growing points increases and plant vigor declines. The period of maturity varies from plant to plant and the maturation process is accompanied by extensive biochemical changes [20].

In this study, the antioxidant activities of *Amaranthus cruentus* increased at later stages while that of *Celosia argentea* also increased up to the 5th week and declined at the 6th week. This suggests that harvesting at advanced age potentially provides the greatest concentrations of antioxidant. Chemical composition of vegetables at different harvesting periods might also be cultivar or species dependent. Sowunmi and Chukwudebe [21] reported that harvesting okra fruits at later stages guaranteed higher

nutrient content. However, decrease in mineral composition of *Amaranthus blitum, A. gongeticus* and *Spinacea oleracea* leaves has been reported as the plants matured [9].

The antioxidant phenolic compounds of *A. cruentus* increased at the later stage except for anthocyanin. This corroborates the findings of Khader and Rama [11]) and Berquist [12], who reported an increase in biologically active compounds of plant leaves studied during the process of maturation. However, there was a decline in the phenolic compounds concentrations of *C. argentea* as the plants advanced more in age.

Production practices sowing time, harvesting time, soil type, irrigation, the type and quantity fertilizer application, plant maturity at harvest and other practices can affect the water and nutrient supply to the plant and therefore also the plant composition and quality. Though, many times these factors are not being taken into considerations by food analysts/researchers, not to talk of consumers. In this study, the optimum period to harvest these vegetables is between 5 to 6 weeks of age, when the antioxidant activities and the concentrations of antioxidant phenol compounds are highest. Moreover, for *A. cruentus*, age at harvest is more crucial compared to *C. argentea* in terms of antioxidant activities.

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