EFFECT OF DRYING TECHNIQUES ON PHYTOCHEMICAL AND VITAMIN COMPOSITIONS OF THREE SPECIES OF AMARANTH

ABSTRACT

This study reviewed the effect of drying techniques on phytochemical and vitamin compositions of *Amaranthus tricolor*,*Amaranthushybridus*, and *Amaranthuscruentus*. Analyses were conducted with respect to fresh, room-dried, oven-dried at 40^{o}C and oven-dried at 60^{o}C treatments from each variety. Standard operating procedures were followed for phytochemicals and vitamins analyses. Statistical analysis was performed using the Statistical Product and Service Solutions (SPSS).Two way analysis of variance (ANOVA) was used to compare the means of various parameters.The phytochemical compositions of *Amaranthus tricolor* leaves ranged between 13.81–15.92mgCE/g, 1.65–2.84mgTAE/g, 1.23–1.63%, 2.04–4.93%, 5.54–10.12mgGAE/g and 0.1–0.19%, for *Amaranthus hybridus* leaves ranged between 12.01–12.71mgCE/g, 1.01–3.65mgTAE/g, 1.37–1.52%, 2.95–6.76%, 3.62–7.83mgGAE/g and 0.16–0.91% while *Amaranthuscruentus* leaves ranged between 15.76–18.83mgCE/g, 0.53–2.90mgTAE/g, 1.75–1.87%, 1.98–4.0%, 5.54–8.35mgGAE/g% and 0.12–0.18% respectively for flavonoids, tannins, saponins, alkaloids, phenols and phytates contents. The range of values of vitamin A contents for *Amaranthus tricolor*, *Amaranthushybridus*and *Amaranthuscruentus*are 7.0–10.52, 8.67–10.61 and 9.09–10.73 mg/100grespectively while the range of values of vitamin C contents for *Amaranthus tricolor*, *Amaranthushybridus* and *Amaranthuscruentus* are 41.60–45.15, 33.80–37.85 and 44.08–50.61 mg/100g respectively. The results indicated that the shade-dried, oven-dried at 40^{o}C and oven-dried at 60^{o}C treatments are best drying techniques for high retention of vitamins and phytochemicals.

Comment [O1]: Contextual Introduction

Comment [O2]: Experimental Design???

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Keywords: Plant,*Amaranthus tricolor*,*Amaranthushybridus*, *Amaranthuscruentus*, room-dried, Oven-dried.

INTRODUCTION

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Plants generate a multitude of chemical compounds that serve diverse purposes, such as defending against insects, fungi, diseases, and herbivorous mammals (Gershenzon and Ullah,

2022). The fresh, edible parts of herbaceous plants are commonly known as vegetables, which are vital to a nutritious diet. They are emphasized in dietary guidelines due to their high levels of dietary fiber, vitamins, minerals (particularly electrolytes), and phytochemicals, especially antioxidants (Slavin and Lloyd, 2012).

The plant Amaranthus spp. is significant in both food and medicine, with its nutritional and ethnomedicinal applications widely utilized globally for preventing and managing certain diseases. Fresh Amaranth plants are plentiful in the summer and rainy seasons but have a short shelf life due to their high moisture content, resulting in nutrient loss and market scarcity (Nighitha and Santhi, 2019). This necessitates prompt processing to prevent substantial nutritional and economic losses and to ensure availability during the off-season at profitable prices (Kiremire*et al*., 2010).

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Amaranth (Amaranthus spp.) is an edible green leafy vegetable native to Central America, including Mexico and nearby countries. It thrives in both temperate and tropical climates and is cultivated for its grains and leaves (Rastogi and Shukla, 2013). The primary species of grain amaranth are *Amaranthuscaudatus, Amaranthuscruentus,* and *Amaranthushypochondriacus,* with *Amaranthushybridus* and *Amaranthus tricolor* being grown to a lesser extent for their leaves (Sharma *et al*., 2012). Fresh leaves from species like *Amaranthus tricolor, Amaranthuscruentus, Amaranthushypochondriacus, Amaranthusdubius, Amaranthusblitum,* and *Amaranthus edulis* are commonly used in soups and salads.

Amaranthus tricolor, also known as Joseph's coat or Red Amaranth, is an edible species cultivated for both ornamental and culinary uses. It is grown annually for its vibrant, colorful foliage rather than its flowers, earning it the name Joseph's coat (Grubben and Denton, 2004).

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Amaranthus hybridus, commonly called Smooth Pigweed or Green, Smooth, or Red Amaranth, is an annual herbaceous plant that reproduces solely through seeds. Its stems are thick, often ribbed, and may have a red tinge. At maturity, the entire plant can turn reddish, and its seeds are round or dark brown (Akubugwo*et al*., 2007).

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Amaranthuscruentus, known as Red Amaranth, is a tall annual herbaceous plant with clusters of dark pink flowers. It reproduces only by seeds and has a short growing period of 4-6 weeks. At maturity, the plant can turn completely reddish (Śmigerska, 2016; Makinde*et al.*, 2010).

Drying is a key traditional method for preserving vegetables. It transforms leafy vegetables into a lightweight product that is easy to transport and store.

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MATERIALS AND METHODS

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Sources of raw materials

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The fresh species of Amaranth were obtained from Aguluezechukwu farmland, AguataL.G.A of Anambra State, Nigeria. These species are *Amaranthus tricolor, Amaranthushybridus*, and *Amaranthuscruentus*; and they were selected based on their high yield and agronomic desirability. The plant sample(s) collected was taken to the Department of Botany, NnamdiAzikiwe University Awka, where it was identified and authenticated by Mr. IrokaChisom, a taxonomist in the Department. A sample(s) specimen was deposited and a voucher number NAUH-062[A], NAUH-232[A] and NAUH-233[A] was issued to *Amaranthushybridus*, *Amaranthus tricolor* and *Amaranthuscruentus* respectively.

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SAMPLE PREPARATION AND DRYING OF THREE SPECIES OF AMARANTH

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This was done in the Food Processing Laboratory of the Department of Food Science and Technology, NnamdiAzikiwe University, Awka, Anambra state. The samples stalks were removed and the samples rinsed with clean running tap water to remove unwanted external material such as dust, soil and other contaminants. The samples were sliced thinly using sharp stainless knife to enable proper drying. Then moisture evaporated using different drying techniques which includes room temperature and oven drying at different temperatures (40°C and 60°C). for 2 days with constant turning over to minimize the extent of fungal growth. The dried samples were ground into fine powder using blender and sieved through a 0.5 mm mesh sieve to obtain a dried powdered samples that were used for analyses. They were packaged in sealed polythene bags to prevent moisture absorption. It was thereafter taken to Alpha Laboratory Awka, Anambra state for further analysis. Anambra state is located in the south-eastern part of Nigeria and situated between latitudes 5° 32' and 6° 45' N and longitude 6° 43' and 7° 22' E, respectively.

Experimental Design

This experiment was laid out in a 3 *x* 4 Factorial Design comprising of 12 treatments and 3 replications shown in the Table 1. The three species A. *hybridus* (AH), A. *tricolor* (AT) and A. *Cruentus*(AC) were studied under fresh, room dried, oven dried at 40°C and oven dried at 60°C conditions, labelled 1, 2, 3 and 4 respectively in Table 1. Each of the species was analyzed for phytochemical and vitamin compositions.

Table 1: Design Matrix

Amaranth	Fresh	Withering (Room drying)	Oven Drying	
			40°C	60°C
A. hybridus	AH_1	AH_2	AH_3	AH_4
A. tricolor	AT_1	AT_2	AT_3	AT_4
A. Cruentus	AC_1	AC_2	AC_3	AC_4

Method of Analysis

Phytochemical Analyses

Determination of flavonoids, saponins and tannins

The flavonoids, saponins and tanninscontent were determined according to the method of Onwuka (2005).

Determination of alkaloids

The alkaloid content was determined according to the method of Harborne (2000).

Determination of phytates

The phytate content was determined according to the method of Young and Greaves (1999).

Determination of total phenols

The phenolic content of the sample(s) was determined according to the AOAC method (2010).

Vitamins Analyses

Determination of Vitamin A (Retinol) and Vitamin C (Ascorbic Acid)

Vitamin A content was determined according to the method of AOAC (2010).

RESULTS AND DISCUSSION

Phytochemical composition of *Amaranth tricolor, Amaranth hybridus, Amaranth cruentus*

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Table 2: Phytochemical Compositions of three Amaranthus Species leaves as affected by drying techniques

Amaranth Species	Drying Technique			
	Fresh (non-dried)	Shade dried	Oven dried (40°C)	Oven dried (60°C)
		Flavonoid (mgCE/ 100 g		
A. tricolor	$15.47^{b}_{x}\pm0.19$	$15.85^{b}_{w}\pm0.03$	$15.92^{b}_{w}\pm0.03$	$13.81^{b}_{y}\pm0.01$
A. hybridus	$11.45^{c}_{y}\pm0.04$	$12.01^{c}_{x}\pm0.01$	$12.71^{c}_{w}\pm0.02$	$12.11^{c}_{x}\pm0.00$
A. cruentus	$19.82^{a}_{w}\pm0.01$	$18.65^{a}_{x}\pm0.03$	$18.83^{a}_{x}\pm0.01$	$15.76^{a}_{y}\pm0.05$
		Tannins (mg/ 100 g		
A. tricolor	$2.14^{b}_{x}\pm0.03$	$2.84^{c}_{w}\pm0.02$	$2.03^{b}_{y}\pm0.02$	$1.65^{a}_{z}\pm0.00$
A. hybridus	$3.53^{a}_{x}\pm0.03$	$3.65^{a}_{w}\pm0.02$	$2.23^{a}_{y}\pm0.03$	$1.01^{b}_{z}\pm0.02$
A. cruentus	$1.92^{c}_{x}\pm0.02$	$2.90^{b}_{w}\pm0.00$	$0.65^{c}_{y}\pm0.01$	$0.53^{c}_{z}\pm0.01$
		Saponins (mg/100 g)		
A. tricolor	$1.51^{c}_{x}\pm0.00$	$1.23^{c}_{y}\pm0.04$	$1.63^{b}_{w}\pm0.01$	$1.26^{c}_{y}\pm0.00$
A. hybridus	$1.76^{b}_{w}\pm0.01$	$1.52^{b}_{x}\pm0.00$	$1.37^{c}_{z}\pm0.00$	$1.46^{b}_{y}\pm0.02$
A. cruentus	$1.86^{a}_{w}\pm0.00$	$1.87^{a}_{w}\pm0.02$	$1.75^{a}_{x}\pm0.01$	$1.86^{a}_{w}\pm0.01$
		Alkaloids (mg/ 100 g)		
A. tricolor	$4.52^{b}_{x}\pm0.02$	$4.93^{b}_{w}\pm0.02$	$2.13^{b}_{y}\pm0.03$	$2.04^{b}_{z}\pm0.04$
A. hybridus	$6.76^{a}_{w}\pm0.01$	$6.76^{a}_{w}\pm0.01$	$3.66^{a}_{x}\pm0.02$	$2.95^{a}_{y}\pm0.03$
A. cruentus	$3.82^{c}_{x}\pm0.02$	$4.00^{c}_{w}\pm0.00$	$2.03^{c}_{y}\pm0.03$	$1.98^{c}_{z}\pm0.02$
		Phenols (mg/ 100 g)		
A. tricolor	$9.20^{b}_{x}\pm0.05$	$10.12^{a}_{w}\pm0.03$	$7.62^{a}_{y}\pm0.02$	$5.54^{a}_{z}\pm0.00$
A. hybridus	$7.78^{c}_{x}\pm0.04$	$7.83^{c}_{w}\pm0.01$	$5.74^{c}_{y}\pm0.00$	$3.62^{b}_{z}\pm0.03$
A. cruentus	$9.62^{a}_{w}\pm0.00$	$8.35^{b}_{x}\pm0.00$	$6.81^{b}_{y}\pm0.01$	$5.54^{a}_{z}\pm0.02$
		Phytate		
A. tricolor	$1.91^{a}_{w}\pm0.04$	$0.10^{b}_{z}\pm0.01$	$0.15^{b}_{y}\pm0.03$	$0.19^{a}_{x}\pm0.01$
A. hybridus	$1.13^{c}_{w}\pm0.01$	$0.17^{a}_{y}\pm0.01$	$0.91^{a}_{x}\pm0.01$	$0.16^{b}_{y}\pm0.00$
A. cruentus	$1.72^{b}_{w}\pm0.00$	$0.18^{a}_{x}\pm0.01$	$0.12^{c}_{z}\pm0.00$	$0.18^{ab}_{x}\pm0.01$

I. *Values are mean ± standard deviation of triplicate determinations*
II. *Values/means with different superscripts within column; and different subscripts along a row are significant ($p < 0.05$)*

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The phytochemicals contents of fresh and dried Amaranthus leaves are shown in Table 2. Fresh *Amaranthuscruentus* had significantly ($p < 0.05$) the highest flavonoid (19.82 mg/100g), Saponins (1.86 mg/100 g) and phenols (9.62 mg/100 g); while *Amaranthus hybridus* specie had the highest tannins (3.53 mg/100 g) and alkaloid (6.76 mg/ 100 g) and *Amaranthus tricolor* had the highest phytate (1.91 mg/ 100g) content. The fresh leaves of *Amaranthus tricolor* had significantly ($p < 0.05$) higher amount of flavonoid than *Amaranthus hybridus* that had 11.45 mg /100 g. Highest amount of the flavonoid was maintained by dried *Amaranthuscruentus* (18.83 – 15.76 mg/ 100 g). Shade drying that took place at about 30 ± 20°C and oven drying at 40°C increased ($p < 0.05$) the content of the flavonoid. This was evident in the values recorded in *Amaranthus hybridus* and *Amaranthus tricolor* leaves. The effect of shade drying and drying at 40°C did not differ significantly ($p > 0.05$) as observed in the *Amaranthus tricolor* with values of 15.85 and 15.92 mg/100 g, respectively; and in *Amaranthuscruentus* with flavored content of 18.65 and 18.83 mg /100 g, respectively. Drying at 60°C significantly ($p< 0.05$) reduced the flavonoid content indicating its heat sensitivity. An average of total flavonoid content of 94.26 RE mg/g DW and 103.16 RE mg/g DW were reported for green and red amaranth, respectively, by Hague *et al* (2022). Umakanta et al (2020) reported a range of 62.54 to 157.40 RE mg/g DW with a mean of 94.81 RE mg/g DW of flavonoid for 12 genotypes of Amaranthuswhile Akubugwo*et al*. (2007) observed a value of 0.83 mg/100 g flavonoid for *Amaranth* hybridus. Khair *et al* (2013) also reported a range of 62.6 to 77.7 GAE mg/g and 53.6 – 70.4 GAE mg/g total flavonoid for two Amaranth species.

Amaranth hybridus leaves had the highest tannin content with 3.53 mg/ 100 g, and lowest in *Amaranth cruentus* with 1.92 mg/100 g. *Amaranthus hybridus* maintained the highest also in the shade dried and 40°C oven dried leaves (3.65 and 2.23 mg/100 g, respectively). The Tannin content increased in the shade dried leaves than in the 40°C oven dried leaves. Drying at 60°C significantly ($p < 0.05$) reduced the tannins content.

Like in flavonoids, *Amaranth cruentus* fresh leaves had the highest saponins (1.86 mg/100 g) and maintained significantly the highest (1.87 – 1.75 mg/100 g) in the dried leaves among other species. Fresh and dried leaves of *Amaranth tricolor* had the lowest saponins content (1.51-1.23 mg/ 100g); and *Amaranth hybridus* the range of 1.76 – 1.37 mg/ 100g. Unlike in tannin and flavonoid, shade drying rather than increasing the saponin content decreased it signifying more

heat sensitivity of saponins. Drying at 40°C and 60°C had more severe effect on the saponins as the content decreased with increasing temperature.

As seen in Table 2, fresh and dried *Amaranthus hybridus* leaves had the highest alkaloid content of 6.76 to 2.95 mg/100g. This was followed by *Amaranthus tricolor* with the content of 4.52 to 2.04 mg/ 100g and then *Amaranthuscruentus* with the lowest content of 4.00 - 1.98 mg/100g indicating that among the three species, *Amaranthuscruentus* had the lowest source. Also just like in flavonoid and tannins, alkaloid content was increased by shade drying that took place at about 30 ± 20°C but was decreased by drying at 40°C and 60°C with the loss in the latter being more severe.

Table 2 revealed that fresh leaves of *Amaranthuscruentus* had significantly ($p < 0.05$) the highest content of phenols (9.62 mg/100g) than *Amaranthus tricolor* that had 9.20 mg/100g and *Amaranthus hybridus* that had 7.78 mg/100g. However, among the dried leaves, *Amaranthus tricolor* had the highest content with the range of 10.20 to 5.54 mg/100g and was followed by *Amaranthuscruentus* with the range of 8.35-5.54 mg/100g and then *Amaranthus hybridus* with 7.83 – 3.62 mg/100g. In all, shade drying conserved the highest phenol content of 10.12, 8.35 and 7.83 mg/100g in *Amaranthus tricolor*, *Amaranthuscruentus* and *Amaranthushybridus* respectively; and oven drying at 60°C the least values of 5.54 and 3.62 mg/100g.

The fresh leaves of *Amaranthus tricolor* had the highest amount of phytate (1.91mg/100g) compared to other species, *Amaranthuscruentus* had (1.72mg/100g) and then *Amaranthus hybridus* (1,13mg/100g). Amaranthus hybridus showed a notable increase in phytate content after drying the species and ranged from 0.16 -0.91mg/100g surpassing the phytate levels of *Amaranthus tricolor* having 0.10 – 0.15mg/100g and *Amaranthuscruentus* 0.12 – 0.18 mg/100g. This suggests that the drying process observed might enhance phytate concentration in *Amaranthus hybridus*.

Table 3: Vitamins A and C compositions of three Amaranthus Species leaves as affected by drying techniques

Amaranth	Drying Technique

Species	Fresh (non-dried)	Shade dried	Oven dried (40°C)	Oven dried (60°C)
		Vitamin A (mg/ 100 g)		
A. tricolor	$10.09^{c}_{x}\pm0.09$	$10.52^{c}_{w}\pm0.02$	$8.95^{b}_{y}\pm0.02$	$7.00^{c}_{z}\pm0.00$
A. hybridus	$10.64^{b}_{w}\pm0.01$	$10.61^{b}_{w}\pm0.01$	$9.05^{a}_{x}\pm0.05$	$8.67^{b}_{y}\pm0.02$
A. cruentus	$10.73^{a}_{w}\pm0.02$	$10.73^{a}_{w}\pm0.02$	$9.13^{a}_{x}\pm0.03$	$9.09^{a}_{x}\pm0.08$
		Vitamin C (mg/ 100 g)		
A. tricolor	$40.18^{b}_{z}\pm0.00$	$43.77^{b}_{x}\pm0.00$	$45.15^{b}_{w}\pm0.02$	$41.60^{b}_{y}\pm0.05$
A. hybridus	$36.25^{c}_{y}\pm0.17$	$36.84^{c}_{x}\pm0.04$	$37.85^{c}_{w}\pm0.04$	$33.80^{c}_{z}\pm0.00$
A. cruentus	$52.03^{a}_{w}\pm0.04$	$50.61^{a}_{x}\pm0.02$	$50.32^{a}_{y}\pm0.01$	$44.08^{a}_{z}\pm0.02$

I. Values are mean ± standard deviation of triplicate determinations
II. Values/means with different superscripts within column; and different subscripts along a row are significant ($p < 0.05$)

The Vitamins A and C compositions of Amaranthus leaves are shown in Table 3. There is a significant ($p < 0.05$) difference among the fresh Amaranthus species and the dried samples occasioned by different drying techniques/temperatures. The Vitamin A content for fresh *Amaranthuscruentus* was highest (10.73 mg/100g) while that of *Amaranthus tricolor* was the lowest (10.73 mg/100g). This trend was maintained in the dried samples where *Amaranthuscruentus* had the highest range of 10.73 mg/100 g to 9.09 mg/100 g; and *Amaranthus tricolor* the lowest range of 10.52 mg/100g to 7.00 mg/100g. *Amaranthus hybridus* maintained a middle range of 10.61 mg/100 g to 8.67 mg/100g. Shade drying did not significantly ($p < 0.05$) affect the vitamin A content of the Amaranthus leaves but drying at 40°C and 60°C did with drying at 60°C being the most severe. Akubugwo*et al.* (2007) reported the vitamin A content of 3.29 mg/100g for sundried leaves of *Amaranthus hybridus*. The quantity of vitamin A in the species of amaranth could play its role in a multitude of physiological processes, which include vision, bone health, immune function and coagulation (Reddy and Jialal, 2002).

Table 3 revealed that Amaranthus leaves had higher amount of vitamin C than vitamin A with *Amaranthuscruentus* maintaining the highest amount of 52.03 to 44.08 mg/100g. However, *Amaranthus hybridus*, had the least amount (36.25 to 33.80 mg/100g). *Amaranthus tricolor* took the middle range of 45.15 to 40.18 mg/100g. Drying at 40°C seemed to have conserved more vitamin C in Amaranthus leaves than Shade drying and drying at 60°C. The variation in vitamin C retention in the shade-dried sample at 40°C might be due to the lower heat drying period (Hussein *et al.*, 2016). The benefit of vitamin C could help boost the body immunity. They

contain bioactive compounds which protect the body from nutritional deficiency diseases and free radicals that cause oxidative damage to cells (Ukom and Obi, 2018).

Conclusion

This study conducted shows that the dried leaves of *Amaranthus tricolor*, *Amaranthushybridus* and *Amaranthuscruentus* have good food values and phytochemical potential in maintenance of healthy living. From the analysis, these species of Amaranth especially *Amaranthuscruentus* (fresh and all treatments) contain good source of health-promoting bioactive chemical constitutes needed in prevention and management of some non-communicable diseases.

Based on the different drying treatments employed, the dried species of Amaranth contained different proportion of nutrients. Drying at 40^{o}C retained a higher proportion of heat sensitive nutrients such as vitamin C

Drying at 60^{o}C, resulted in greater degradation of heat sensitive nutrients due to the higher temperature. The result of this study indicates that the best drying technique for high retention of vitamins and phytochemicals, food values, and vitamins in these samples is shade drying.

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