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Postharvest UV-C application to improve health promoting secondary plant compound pattern in vegetable amaranth

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ABSTRACT

Vegetable amaranth (*Amaranthus cruentus* L.) is gaining importance among the African indigenous leafy vegetables (AIVs) in the diets of many households in Africa. However, improper processing, handling, and storage of AIVs often result in faster deterioration thus high quantitative and qualitative losses with reduced availability of these highly nutritive and health promoting plants. Targeted application of UV-C has been shown to induce beneficial physiological responses of crops after harvest. The present study was conducted to evaluate the effects of postharvest UV-C application on health promoting secondary plant compounds of vegetable amaranth cv. Madiira. Eight weeks after planting, leaves were harvested and treated with UV-C (254 nm) at either 1.7 kJ m^{-2} or 3.4 kJ m^{-2} while untreated leaves served as control. The leaves were kept up to 4 d and 14 d at 20 °C (65% RH) and 5 °C (85% RH), respectively. Characteristic health promoting plant compounds, such as vitamin E, carotenoids, flavonoids, phenolic acids, as well as glutathione peroxidase (GPOX) activity and antioxidant capacity (TEAC) and their correlations were analyzed. Results showed that the accumulation of secondary metabolites was dependent on UV-C dosage, storage temperature and duration. Vitamin E, carotenoids (e.g. lycopene, β-carotene and lutein), flavonoids (e.g. quercetin and kaempferol derivatives), phenolic acids (e.g. ferulic, coumaric and caffeic acid derivatives) as well as GPOX activity and TEAC increased in UV-C treated vegetable amaranth leaves compared with the untreated samples. Furthermore, there was a relationship in most studied secondary compounds and TEAC. The UV-C effects at both storage conditions were comparable for most studied compounds while storage duration variedly affected the compounds studied. The increase in the studied secondary plant compounds is attributed to their plant defense mechanism against oxidative damage of plant tissues by UV-C irradiation. This could be an important strategy in reducing the loss of secondary plant compounds, hence maintaining nutritional and health promoting properties of AIVs during postharvest supply chain.

1. Introduction

Vegetable amaranth (*Amaranthus cruentus* L.) is one of the African indigenous leafy vegetables (AIVs) characterized by fast growing and a high tolerance towards arid conditions and poor soils in comparison to other exotic (introduced) crops cultivated under unfavourable conditions in Kenya (Abukutsa-Onyango, 2003). Therefore, it is part of the diets supplying adequate amounts of protein, vitamins, dietary fiber, and other important nutrients, and furthermore contributing to the incomes of rural and urban households in Africa (Chelang'a, Obare, & Kimenju, 2013). Moreover, AIVs are known for their health promoting properties, such as anticarcinogenic, antiinflammatoric, antihistaminic, and antitumor activities (Nana, Hilou, Millogo, & Nacoulma, 2012). In fact, especially vegetable amaranth has been used curatively for diarrhea, dysentery, ulcers, and intestinal haemorrhaging (Nana et al., 2012). The curative effects are attributed to secondary plant metabolites, such as vitamins, carotenoids, flavonoids, and phenolic acids (Nana et al., 2012). As such, it can play an important role in improving food health, nutrition, and security, especially in Sub-Saharan Africa. Secondary plant metabolites are also of interest because of their use as

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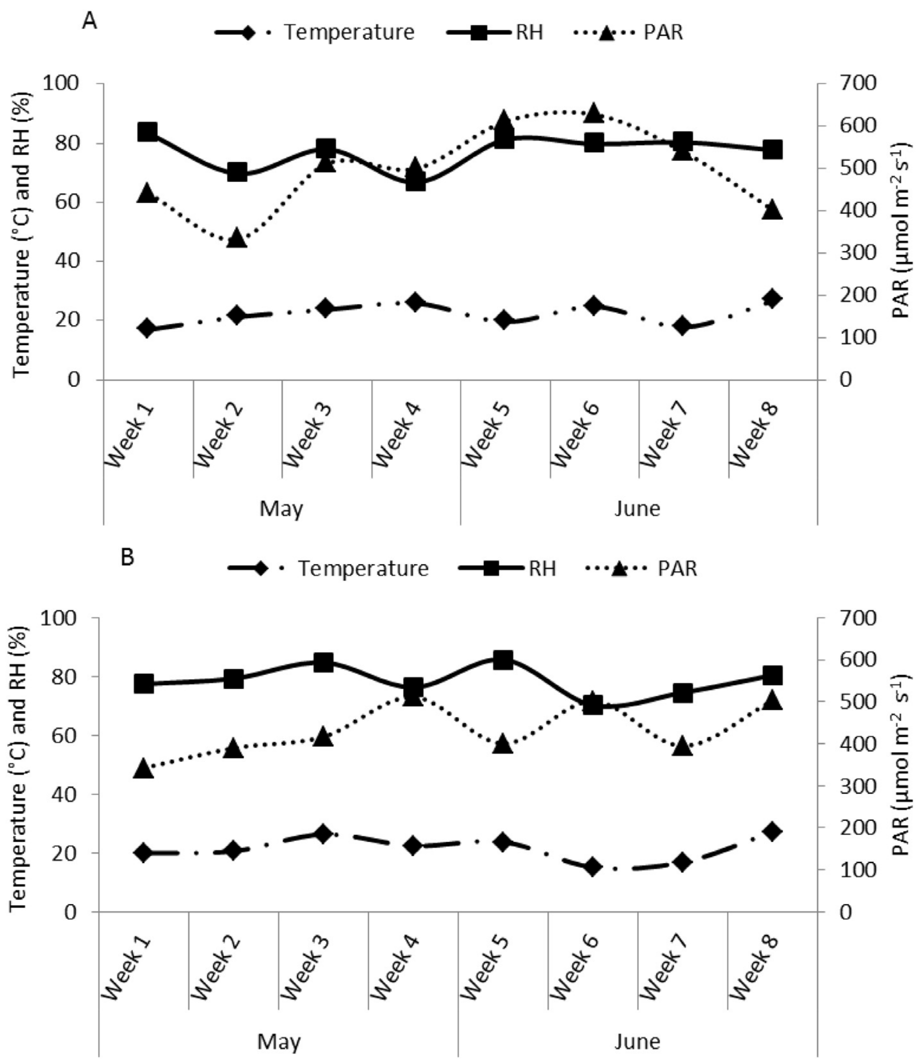

Fig. 1. Greenhouse microclimate conditions (A-2015 and B-2016) during the production of vegetable amaranth at Humboldt-Universität zu Berlin, Germany.

dyes, fibres, oils, waxes, and, flavouring agents and they are viewed as potential sources of antibiotics, replacement of synthetic food additives, insecticides, and herbicides (Kasote, Katyare, Hegde, & Bae, 2015). In the past, the increasing global health awareness has led to an upsurge of interest focussing on secondary metabolites in fruits and vegetables and their human health related impacts. However, improper processing, handling, and storage of AIVs often result in deterioration and high quantitative and qualitative losses with reduced availability of these health promoting plant compounds (Gogo, Opiyo, Ulrichs, & Huyskens-Keil, 2016). This has promoted research in the field of postharvest technology to determine how the content of secondary plant metabolites can be maintained or even improved during the postharvest food supply chain (Schreiner & Huyskens-Keil, 2006). The concentration of various secondary plant compounds is controlled by genetic processes, in addition to being influenced by environmental factors, e.g. UV irradiation, temperature, irrigation, and soil and nutrients amendment (Caverzan, Casassola, & Brammer, 2016). Among various impact factors, UV-C (200–280 nm) is reported to be one of the important variables affecting secondary metabolites in plants (Ribeiro, Canada, & Alvarenga, 2012).

Postharvest treatments based on UV-C have been widely used with sterilization purposes in the fields of health, microbiology, and food processing due to its germicidal properties (Ribeiro et al., 2012). Furthermore, low doses of UV-C are known to induce beneficial responses in biological systems and particularly in plant tissues, where the concept underlying the strategy is known as hormesis (Ribeiro et al., 2012). UV-C postharvest treatments of fruits and vegetables have proven to be effective in delaying ripening and senescence, diminishing decay, and even in increasing health promoting secondary plant compounds in fruit and vegetables (Pataro, Donsi, & Ferrari, 2015; Ribeiro et al., 2012; Schreiner & Huyskens-Keil, 2006). The latter plant responses are caused due to the fact that UV-C acts as an abiotic physical elicitor of stress resistance mechanisms leading to a rapid stimulation of the synthesis of secondary plant metabolites, such as vitamins, carotenoids, flavonoids, and phenolic acids (Ribeiro et al., 2012). Studies on UV-C mediated increase in secondary metabolites and antioxidative potential have been reported (Pataro et al., 2015; Ribeiro et al., 2012). These studies have been demonstrated for various vegetables such as red cabbage (*Brassica oleracea* var. *capitata f. rubra*) (Zhang et al., 2016), broccoli (*Brassica oleracea* L. var. *italica*) (Costa, Vicente, Civello, Chaves, & Martínez, 2006; Khalili, Shekarchi, Razavi, & Rastegar, 2017; Lemoine, Civello, Chaves, & Martínez, 2008), Chinese kale (*Brassica oleracea* var. *alboglabra*) (Chairat, Nutthachai, & Varit, 2013), tatsoi (*Brassica rapa* L. var. *rosularis*) (Tomás-Callejas, Otón, Artés, & Artés-Hernández, 2012), and spinach (*Spinacia oleracea* L.) (Artés-Hernández, Escalona, Robles, Martínez-Hernández, & Artés, 2009). In addition, treatments with UV-C potentially present several advantages for the food producing industry as it does not leave residues on the products, has no legal restrictions, and does not require complex equipment (Ribeiro et al., 2012).

Based on the advantages of postharvest UV-C application for fruits and vegetables and the lack of knowledge on its effects on AIVs; the