White Paper

The Effect of UV Irradiance on NZ grown Fruits and Vegetables

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A great deal of prior research has been done focusing on the danger to humans, and damage to crops, from increased exposure from solar radiation (specially UV-B), associated with a reduction in ozone layer around New Zealand and Australia. It is well known by climate scientists that New Zealand represents a unique case study into the effects of increased UV irradiation when compared to countries of similar latitude in the Northern Hemisphere. Previous measurements of UV radiation in New Zealand and Germany have shown the UV irradiances in New Zealand to be much greater than in Germany. For example, summertime erythemally weighted (i.e., sun burning) irradiances measured at Lauder, New Zealand, are 40% greater than those measured at the same solar zenith angle at Garmisch-Partenkirchen, Germany [Seckmeyer and McKenzie, 1992[1]; Seckmeyer et al., 1995[2]].

Additionally we now know that certain plants, which are also consumed as part of the human food supply, actually respond to these elevated levels of UV-B by increasing the production of secondary metabolites as part of the plant's stress response to UV-B. These secondary metabolites then act in a way to protect the plant from further UV irradiation and to repair the damage that has already been done by UV-B exposure.

In a 2009 review of the effects of UV-B irradiation on certain plants that are used in the production of compounds useful as medicines or raw materials for manufacture of medicines, the authors described the influenced on these plants by ultraviolet radiation, particularly by UVB radiation (280–315 nmwavelength). The compounds considered in that review were flavonoids, other phenolics, alkaloids (especially indole terpenoid and purine alkaloids), essential oils, terpenoids, glucosinolates and isothiocyanates, as well as phytoestrogens (compounds having human hormone-like activity). The review concluded that in each case the biologically active compound under review could be elevated through the additional exposure to solar radiation.[3]

Of interest, is the substantial body of evidence, which shows the significant effects of UV-B radiation on bioactive compounds such as flavonoid and hydroxycinnamic acid production. These two groups of compounds can act as plant sunscreens, thus providing protection for the plants against UV-B radiation. But importantly they also improve the overall antioxidant potential of the human diet because these natural bioactive compounds themselves also exhibit potent antioxidant properties. For example, certain flavonoids, as well as hydroxycinnamic acids, can act as powerful one-

[1] Seckmeyer, G., and R. L. McKenzie, Increased ultraviolet radiation in New Zealand (45_S) relative to Germany (48_N), Nature, 359, 135 – 137, 1992.
[2] Seckmeyer, G., et al., Geographical differences in the UV measured by intercompared spectroradiometers, Geophys. Res. Lett., 22, 1889–1892, 1995
[3] W.J. Zhang, L.O. Björn / Fitoterapia 80 (2009) 207–218

electron scavengers of free radicals[4]

To test the association between exposure to UV-B radiation and the increase in secondary metabolites in plants, the leaves of different plant species have been studies and a positive correlation of the total flavonoid content with enhanced UV-B radiation has subsequently been well documented under greenhouse conditions[5]. This research also extends to plants grown in cell suspension culture[6]. This assumption however that UV-B irradiation has an impact on levels of UV-B protective compounds in plants has been tested in only a limited number of studies in the field[7].

Subsequently this growing body of research appears to support the assertion derived through observation and anecdote, that New Zealand grown plants for the functional food and nutraceutical industry generally have higher levels of biologically active and beneficial compounds, than the same cultivars grown in other regions of the world.

In one case, during the mid 1990's, a green tea growing plantation was established in Motueka, near Nelson. With significant investment from Sumitomo, Japan, the growing region was selected for its direct climate and agronomic similarities to the top green tea growing regions of Japan. The business assumption was that using the identical green tea cultivars and harvest methods as those used in Japan; Motueka, NZ would become a premium producer of green tea to the Japanese market during the off season. Since green tea is graded according to its "brewed colour" in the cup, the venture was hopeful of high returns. Unfortunately it was discovered during the first harvest that colour of the brewed tea was yellow and not green due to the loss of chlorophyll in the leaf associated with high UV-B levels. This resulted in a significant lowering of the value of the harvest. It was later determined that the only solution for the growers was to put the crop under shade cloth, but this was considered economically unfeasible and the venture when into receivership. Prior to the demise of the green tea venture in Motueka, a business unit called Tasman Extracts, then owned by Tasman Milk Products Ltd, tested the Motueka green tea for its phytonutrient value. The result was a total phenolic value (from HPLC) for green tea that was significant higher than any other sample of green tea ever tested by that company[8].

In another case study in 2000, a company, which is based in the high elevations of the Cascade Mountains in Washington State, USA, purchased the Pawera cultivar of red clover seed from New Zealand because of the reputation this plant had for producing elevated levels of isoflavones. Novagen Laboratories Pty Ltd in Australia had developed a high isoflavone nutritional supplement based exclusively around the high isoflavone yield in the Pawera cultivar grown in New Zealand. In 2000 after taking delivery of the Pawera seed, the US based company also expected to produce a high yielding isoflavone raw material for a customer in Europe in the dietary supplement market. However after the first harvest, the isoflavone level in the red clover appeared little different from the red clover traditionally grown in this region. The company abandoned this project and went back to growing the previous cultivar of local red clover, which was much less expensive to acquire seed for. However, it was later shown during a subsequent growing trial that flattening a mature Pawera red clover crop with a tractor pulled roller, a few days before harvest showed a massive improvement in isoflavone levels which were then in line with isoflavone levels found in the New Zealand grown material. This all supported the hypothesis that it was environmental stress that induced these metabolites and the plant was relatively agnostic to the source of stress.

The third another case study occurred in the production of the 2008-2009 harvest when a group of sweet cherry growers from Central Otago were seeking to better understand the nutritional value of their crop and look to potentially diversify their product offering. This process resulted in the analytical assessment of total phenolics and anthocyanin levels in the cherry. These results were then compared to the results from the same

[4] J.C. Luis et al. / Food Chemistry 101 (2007) 1211–1215

[5] Wulff, A., Anttonen, S., Pellinen, R., Savonen, E.-M., Sutinen, M.-L., Heller, W., Sandermann Jr., H., Kangasjarvi,, J., 1999. Birch (Betula pendula Roth.) responses to high UV-B radiation. Boreal Environ. Res. 4, 77e88.

[6] Min-Soo, K., Lee, W.-K., Kim, H.-Y., Kim, C., Ryu, Y.-W., 1998. Effect of environmental factors on flavonol glycoside production and phenylalanine ammonia-lyase activity in cell suspension cultures of Ginkgo biloba. J. Microbiol. Biotechnol. 8, 237e244.

[7] C. Zidorn et al. / Biochemical Systematics and Ecology 33 (2005) 855e872

[8] Personal observation; Employed by Tasman Extracts at the time.

cultivars grown in cherry growing regions of California and Oregon, USA and tested by UC, Davis. The New Zealand grown cultivars resulted in fruit with significantly higher in both total phenolics and anthocyanin levels. The total phenolics the Central Otago fruit was shown to be 60% higher than the same cultivar grown in the United States. The antioxidant value (measure based on ORAC value) of the Central Otago Fruit was 300% higher when compared to the values found in the fruit from the same US-grown cultivar[9].

The hypothesis of our proposed research is to identify a number of economically valuable, New Zealand grown fruit and plant crops and then compare the phytonutrient profile with the same crops (specific cultivars) grown on a commercial basis in other markets around the world. This would create a future benchmark and the benefit would be to establish a nutrient profile for those NZ fruit and plant crops, naturally grown under high UV radiation and subsequently establish a NZ regional standard for phytonutrient/antioxidant quality.

[9] Confidential data held on file by Quantec Ltd, Hamilton NZ.