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Antioxidant activity of asparagus – Part 2

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A report prepared for
New Zealand Asparagus Council

Copy 5 of 5

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Contents

1 Executive summary

This report describes the results of the second part of a project carried out for the New Zealand Asparagus Research Council. Results are presented for the continued investigation of the antioxidant activity of asparagus, including cultivar variation, effect of processing, influence of spear size and seasonal variation. The distribution of antioxidants along the spear was also examined to determine the potential of waste streams (discarded base of spear) for extraction of a nutraceutical. Based on 2000/01, results two measurements were carried out on the samples: total phenolics (using Folin-Ciocalteu's reagent) and antioxidant activity (by the ABTS assay).

The main findings of the research were:

- *Considerable cultivar variation:* A total of seven cultivars were examined (Crop & Food breeding line B (C&FB), Jersey Giant, JWC1, Pacific 2000, Pacific Purple, Taramea and UC 157). An even greater variation in total phenolics and antioxidant activity was observed compared to 2000. Total phenolics varied between 73.37 and 124.93 mg GAE/100 g fresh weight (FW) (108-126 mg GAE/100 g FW in 2000), while antioxidant activity ranged from 449.27 to 724.22 μmol TEAC/100 g FW (566-754 μmol TEAC/100 g FW in 2000). In both cases Taramea had the lowest levels and JWC1 the highest levels. It was noted that a significant proportion of the cultivar differences were related to spear diameter, but not length.
- *An inverse correlation between spear size and antioxidant activity:* Across all four cultivars examined (JWC1, Pacific Purple and UC 157) there was a significant trend of decreasing antioxidant activity with increasing spear diameter. No correlation was observed between antioxidant activity and spear length (although this was less variable).
- *Significant season-to-season variation:* Three cultivars (UC157, Jersey Giant and C&FB) grown at Lincoln were examined in both 2000 and 2001. In all three cultivars the total phenolic levels and antioxidant activity were significantly lower in 2001 compared to 2000. This may have been due to lower sunlight hours in 2001. Other fruit and vegetables have shown similarly lower levels of antioxidant activity this season.
- *Decreasing antioxidant activity from tip to base:* In both cultivars examined (Pacific Purple and UC 157) antioxidant activity and total phenolic levels were greatest in tip of the spear and tapered off down to the base.
- *Effect of cooking:* There was a small drop in both antioxidant activity and total phenolic content with cooking (steaming), but this was not

significant. Thus, asparagus is a good source of dietary antioxidants even when cooked.

- *Some phase 2 enzyme induction activity:* Although lower than brassica vegetables, asparagus did show some induction of phase 2 enzyme activity, and so may be helpful in cancer prevention.

In all experiments there was a strong correlation between total phenolic content and antioxidant activity, as was observed in 2000 samples. These results back up our findings from 2000/01 that asparagus is a good dietary source of antioxidants (primarily the flavonoid rutin). Since the base of the asparagus spear is relatively low in antioxidants it may not be an ideal starting material for extraction of a nutraceutical. However, based on our findings that spear diameter is inversely correlated with antioxidant activity, reject thin spears may have some usage. Further investigation of this may be warranted.

2 Background

The first part of the project was completed in 2000/01 (Lister 2001) and that report detailed the results of a series of experiments to investigate the levels and activity of antioxidants present in New Zealand-grown asparagus. To summarise, six cultivars or breeding lines were examined, and comparisons were also made between fresh and canned asparagus. The average contents of antioxidant components for asparagus were:

- **phenolics** (determined by HPLC): 103 mg/100 g fresh weight (FW) for fresh asparagus and 47 mg/100 g FW for canned asparagus,
- **carotenoids**: 0.98 mg/100 g FW for fresh asparagus and 0.54 mg GAE/100 g FW for canned asparagus,
- **antioxidant vitamins**: typical values are 11 mg/100 g FW for vitamin C and 0.16 mg/100 g FW for vitamin E.

Quantifying "total phenolics" by Folin-Ciocalteu reagent gave approximate values for total phenolics plus vitamin C. These figures were, on average, 117 mg GAE/100 g FW for fresh asparagus and 60 mg GAE/100 g FW for canned asparagus. The average antioxidant activity of fresh asparagus was 664 μmol TEAC/100 g FW and 303 μmol TEAC/100 g for canned asparagus. There were some variations in antioxidant components and activity between the cultivars examined. Compared to other vegetables, asparagus had very strong antioxidant activity; of the vegetables we have examined to date only watercress and red leaf lettuce have had higher activity on an equal weight basis.

These results indicated that there is potential for asparagus to make a significant contribution to the antioxidant activity of the diet and may be useful for inclusion in supplements and functional foods. Further research is required to substantiate the health benefits of asparagus and to determine the potential of waste streams for extraction of a nutraceutical. On this basis the following areas were investigated further for this part of the project:

- *Cultivar variation.* In an effort to identify cultivars with superior characteristics we examined some further cultivars, particularly those with diverse origins (as advised by Peter Falloon).
- *Seasonal variation.* By examining some of the same cultivars as we did in 2000 we can get some idea if there is variation in activity from season to season.
- *Effect of processing.* Since most asparagus is consumed cooked we had a preliminary look at what effect standard cooking had on antioxidant activity.
- *Potential of waste product.* There is no information on the distribution of antioxidant activity or components in the spear (i.e. whether they are located throughout, or are higher in the tip or butt). Because there is a large amount of wastage (butt ends of spear) each year, if this did contain significant amounts of antioxidants this could provide a valuable product (depending on costs involved in extraction, etc.).
- *Activity in other assays.* To date we have only measured the antioxidant activity of asparagus using the ABTS assay, which measures free radical scavenging ability. We looked at phase 2 enzyme induction activity, which may be useful for assessing the chemoprotective (cancer) activity of plant components.

Based on previous results we measured antioxidant activity (primarily by ABTS assay) and also total phenolics (using Folin-Ciocalteu's reagent and which also accounts for some of the vitamin C). Carotenoids make less contribution to antioxidant activity and so were not measured in this part of the project.

3 Methods

3.1 Collection of samples

Samples were collected from three different locations: the Crop & Food Research site at Lincoln, Peter Falloon's property, Canterbury and Tender Tips, in the North Island. Sample details are given in the Appendix. Each sample consisted of six spears and triplicate samples were taken for each treatment (i.e. data for each treatment is an average from 18 spears).

3.2 Preparation of samples

For most treatments asparagus was prepared as would be standard for home preparation. Any soil was removed and the base of the spear broken off at the "snap" point (with the exception of distribution samples). Individual spear diameter, length and weight were recorded. Treatment groups were assembled, each sample of six spears was weighed (to obtain fresh weight) and where necessary treatments were performed (as detailed below). Samples were then freeze-dried and reweighed (to obtain dry weight). Until analysis samples were stored in airtight bags in the dark at -20°C.

To prepare extracts for analysis approximately 1 g equivalent of fresh weight of each sample was weighed out and extracted with 10 ml of 80% acetone. After four hours extraction in the cold and dark the samples were centrifuged and the supernatant used for subsequent analysis. Triplicate extractions were performed on each sample.

3.2.1 *Cultivar variation*

A total of seven cultivars were examined (Crop & Food breeding line B (C&FB), Jersey Giant, JWC1, Pacific 2000, Pacific Purple, Taramea and UC157) and prepared in the standard manner. Two cultivars (Jersey Giant and UC 157) were obtained from two different locations (Crop & Food Research and Peter Falloon). Three of the cultivars (Crop & Food B, Jersey Giant and UC157) were the same as analysed in 2000. There were a total of nine samples and these were coded 1-9 (refer to Appendix).

3.2.2 *Spear size*

For four cultivars (JWC1, Pacific Purple, Taramea and UC157) spears were separated into two or three groupings based on spear diameter. These samples were coded 10-20 (refer to Appendix).

3.2.3 *Distribution of antioxidants along the spear*

The first sample to be obtained (cultivar UC 157) was harvested at ground level. These spears were cut into five sections, each five centimetres long, and were coded 21 (tips) – 25 (base) (refer to Appendix).

The second set of samples consisted of two cultivars (Pacific Purple and UC 157), these were harvested below ground and had a white base (Figure 1). For each cultivar the first section (a) consisted of the tips and varied between 4 and 13 cm, depending on the total spear length. Two middle sections were each 10 cm long (sections b & c), while the final section (d) comprised the white below ground part that was approximately 4-8 cm long. These samples were coded 26-29 for Pacific Purple and 30-33 for UC 157 (refer to Appendix).

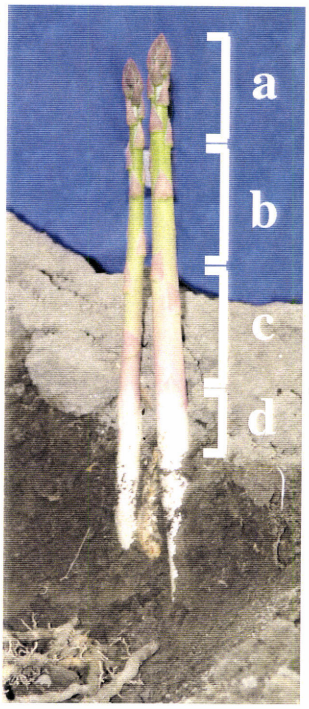

Figure 1: Sections taken to investigate distribution of antioxidants in asparagus spears.

3.2.4 *Effect of cooking*

A sample was collected of Jersey Giant harvested at Crop & Food Research, Lincoln. Half the sample was prepared raw and the other half cooked, using a Sunbeam steamer (cooking time approximately 10 minutes). Samples were coded 34 and 35 (refer to Appendix).

3.3 *Quantification of antioxidant components*

3.3.1 *Total phenolics*

Total phenolics were measured in the acetone extracts using Folin-Ciocalteu's reagent (Spanos & Wrolstad 1990). As discussed in the earlier report (Lister 2000) this measure also takes into account some of the vitamin C. Some of the acetone extracts had to be concentrated before analysis to bring them into an acceptable absorbance range. Gallic acid was used to prepare a standard curve and results were expressed in milligrams of gallic acid equivalents per 100 gram fresh weight (mg GAE/100 g FW). Total phenolic assays were carried out in duplicate on each sample.

3.4 *Measurement of antioxidant activity*

3.4.1 *ABTS assay*

Antioxidant activity was measured using a modified ABTS assay (Miller & Rice-Evans 1996, 1997). Duplicate assays were performed on each extract and at three different dilutions. The assay system is based on generating a free radical (which is coloured) and the ability of an extract to quench the

radical and return it to a non-coloured "harmless" form. This method compares antioxidant activity of the extracts to Trolox, a water-soluble vitamin E analogue. Results are expressed as the amount of Trolox equivalent antioxidant capacity per 100 grams of fresh weight of material (µmol TEAC/100 g FW), which represents the amount of Trolox (vitamin E) that gives the same response as one hundred grams.

3.4.2 *Phase 2 enzyme induction*

Induction of quinone reductase (QR) activity has been successfully utilised as a screening tool to determine cancer chemoprotective chemicals in plant foods (Zhang et al. 1992). Induction of quinone reductase was measured in Hepa 1c1c7 murine hepatoma cells grown in 96-well microtitre plates. Cells were introduced into each well, grown for 24 hours, and then induced for 48 hours by exposure to asparagus extracts (three cultivars were examined: Jersey Giant, Pacific Purple and Taramea). After the induction period, cells were lysed with digitonin. Assessment of cytotoxicity was by measurement of protein concentration. QR activity was assayed by the addition of a reaction mixture containing a NADPH-generating system, an intermediate electron acceptor, menadione, and MTT. QR catalyses the reduction of menadione to menadiol by NADPH, and MTT is reduced by menadiol resulting in the formation of a blue-brown tetrazolium salt. QR inhibitor, dicumarol, stops the reaction after 5 mins, and absorbance read at 490 nm.

4 *Results and discussion*

4.1 *Cultivar variation*

The levels of total phenolics and antioxidant activity of asparagus cultivars are given in the table in the Appendix. There was considerable variation in both the phenolics and antioxidant activity (Figure 2). Total phenolics varied between 73.37 and 124.93 mg GAE/100 g FW, while antioxidant activity ranged from 449.27 to 724.22 μmol TEAC/100 g FW. In both cases Taramea had the lowest levels and JWC1 the highest levels. Despite its purple colour (anthocyanin content) Pacific Purple did not have high antioxidant activity and was in the middle of the range. This was unlike the purple cultivar examined in 2000, which did have the highest activity (although not exceptionally so). As with the 2000 samples there was a strong correlation between total phenolic content and antioxidant activity for the nine samples (R^2=0.98).

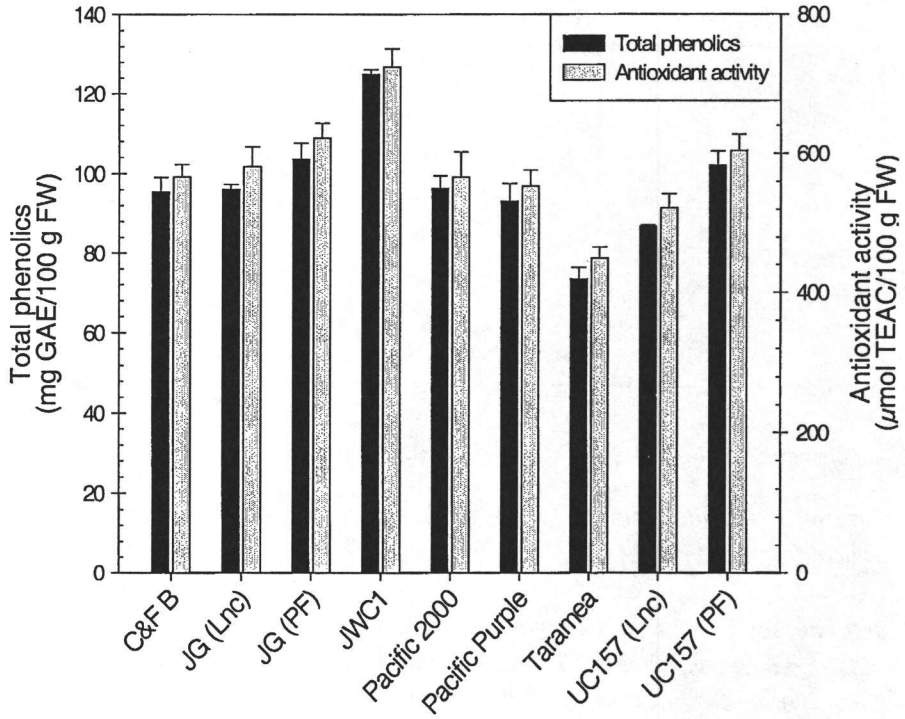

Figure 2: Antioxidant activity of different asparagus cultivars/breeding lines. Error bars show standard deviation.

Compared to our work in 2000 more details on samples were collected this season, such as spear diameter and length. It was noted that there appeared to be a relationship between spear diameter and antioxidant activity (Figure 3a) and similarly spear diameter and total phenolics. The reason for Taramea having low antioxidant activity may be that the average spear size was much greater than for the other cultivars. Pacific Purple likewise had relatively large spears. However, there was no relationship between spear length and antioxidant activity (Figure 3b), although there was less variability in spear length.

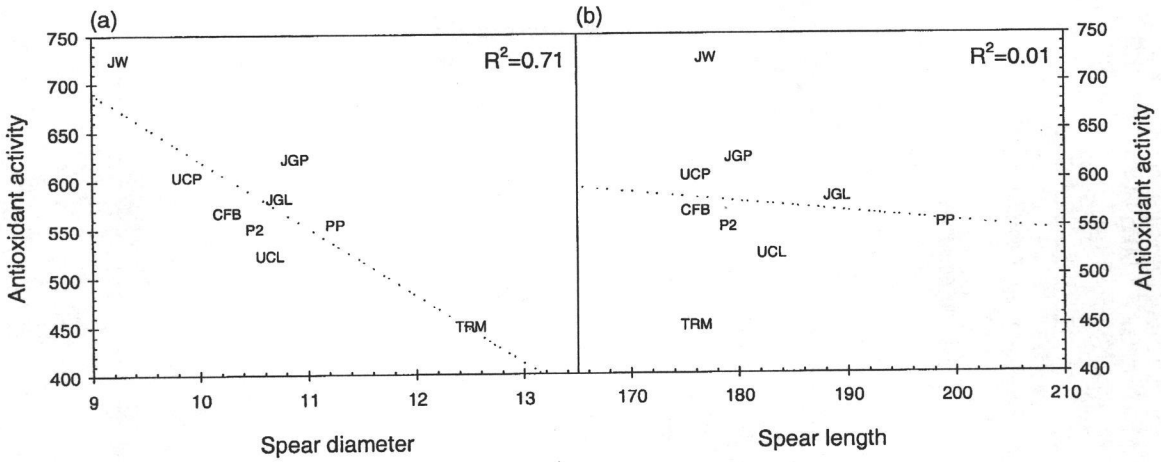

Figure 3: Relationship between spear diameter or spear length and antioxidant activity. Letter codes represent each sample (JW=JWC1; UCP=UC157 from Peter Falloon; JGP=Jersey Giant from Peter Falloon; JGL=Jersey Giant from Lincoln; CFB=Crop & Food breeding line B, as for 2000; P2=Pacific 2000; PP=Pacific Purple; UCL=UC157 from Lincoln; TRM=Taramea). Dotted line is the regression line.

4.2 Influence of spear size

To test the hypothesis that spear size influences antioxidant activity, four cultivars were grouped into thin, medium and thick spear diameter. Because of the different nature of the cultivars the measurements for these groupings were not consistent between cultivars. Across all four cultivars examined there was a significant trend of decreasing antioxidant activity with increasing spear thickness (Figure 4). This indicates that the phenolics and antioxidant activity are higher in the outer layer of the spear (in a small diameter spear there is a greater volume of surface to pith). In many fruit and vegetables (e.g. in apple, potatoes) the greatest concentration of phenolics is often in skin and these compounds may protect the plant from UV damage. Thin spears are often rejected during grading and since these are highest in antioxidants they may be a useful material for extraction of a nutraceutical.

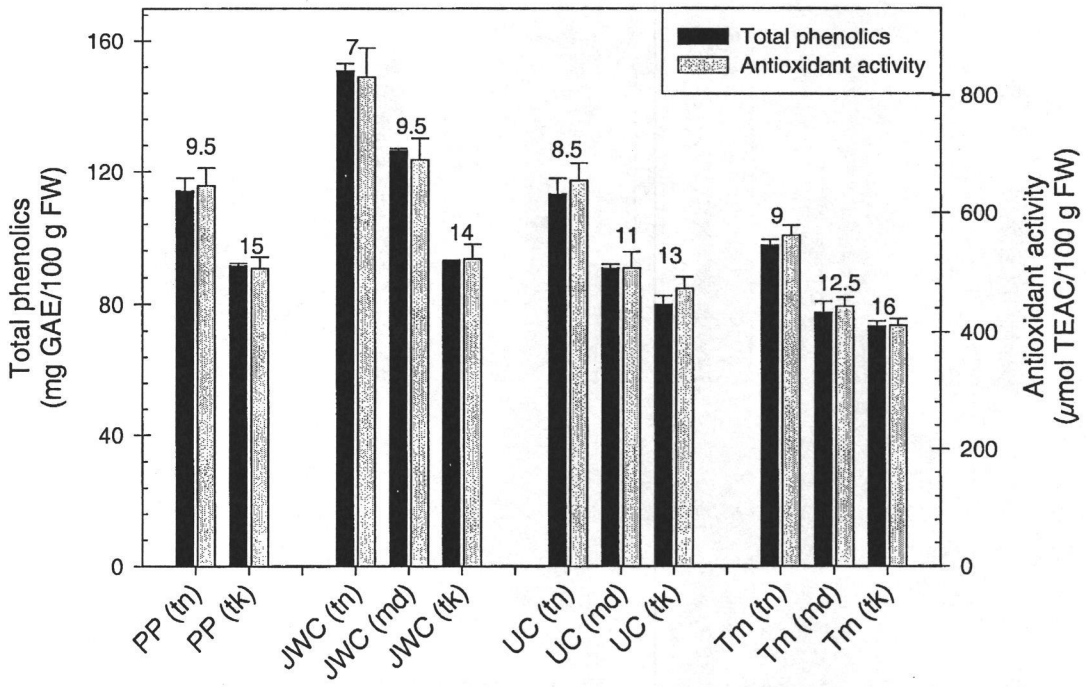

Figure 4: Influence of spear size (tn=thin, md=medium; tk=thick) on phenolic content and antioxidant activity. PP=Pacific Purple; JWC= JWC 1; UC=UC157; Tm=Taramea. Figures given above the bars are the average spear diameter in millimetres for each group. Error bars show standard deviation.

4.3 Season to season variation

In 2000, the average total phenolic content of fresh asparagus was 117 mg GAE/100 g FW (range 108-126 mg GAE/100 g FW) and the average antioxidant activity was 664 μmol TEAC/100 g FW (range 566-754 μmol TEAC/100 g FW). These figures were much lower in 2001, being 97 mg GAE/100 g FW for total phenolics (range 73 and 125mg GAE/100 g FW) and 575 μmol TEAC/100 g FW for antioxidant activity (range 449 to 724 μmol TEAC/100 g FW). However, there were some differences in cultivars examined, which may give rise to differences, so it is important to compare the same cultivars. Three cultivars (UC157, Jersey Giant and C&F A), grown at Lincoln, were examined in both 2000 and 2001. In all three cultivars the phenolic levels and antioxidant activity were significantly lower in 2001 compared to 2000 (Figure 5). We have noted similar trends with other fruit and vegetables we have tested this season (all being lower that previous seasons). One of the reasons for the lower activity in 2001 may be due to more cloudy weather and lower light levels. During the 2000 harvest there was 1629.3 MJ/m^2 of sunlight over the growing season and last year there was only 1129.4 MJ/m^2. Light is well known to induce phenolic levels and hence influence antioxidant activity.

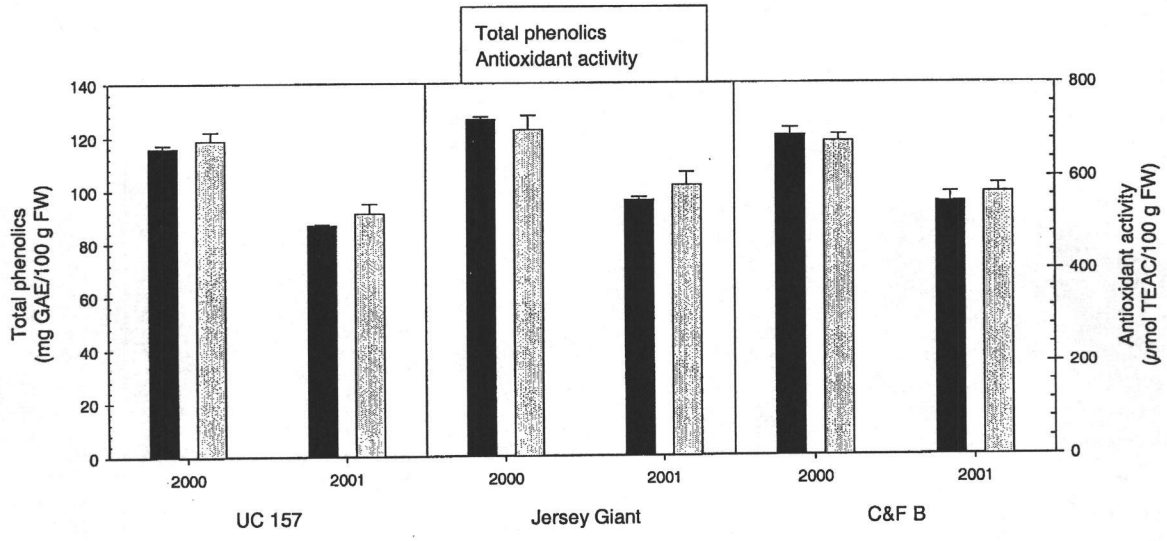

Figure 5: Differences in total phenolics and antioxidant activity of three asparagus cultivars between 2000 and 2001 seasons.

4.4 Growing location

Two cultivars were analysed from two different growing locations, both within Canterbury (due to ease of sampling and elimination of possible influences of transportation). For Jersey Giant there was only a small difference between the two samples (Figure 6). These samples had similar spear diameter, which was shown to have a significant bearing on total phenolics and antioxidant activity. However, there was a significant difference between the two UC 157 samples (Figure 6). The sample grown at Crop & Food Research, Lincoln, was significantly lower in both antioxidant activity and total phenolic content. One of the reasons for this difference may have been that the average spear diameter was greater for the Lincoln sample (10.64 mm compared to 9.88 mm). The relative order of Jersey Giant and UC 157 was the same at both locations; Jersey Giant was higher than UC 157.

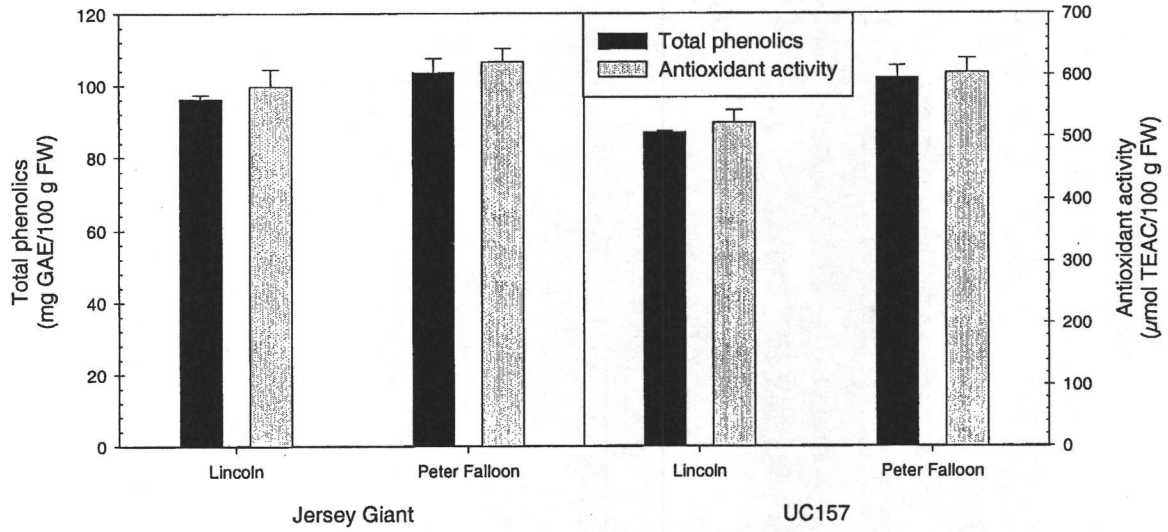

Figure 6: Influence of growing location on levels of total phenolics and antioxidant activity of two asparagus cultivars.

4.5 Distribution of antioxidants along the spear

To determine where in the spear the antioxidants were located, asparagus spears were cut into various sections. Clearly, the antioxidant activity and total phenolic levels were greatest in the tip and tapered off down to the base (Figures 7 & 8). Unfortunately, the white butts (below ground) contain fairly low levels of phenolics and hence antioxidant activity. Part of the reason for low levels below ground may be that they receive no light (light is often essential for synthesis of flavonoids, a main grouping of phenolics) but there may be other reasons. Even the bottom above ground portion (the part that would normally be discarded during processing) had significantly lower activity than the tip or the whole spear. The tips may be higher in antioxidant activity partly due to their greater surface area. It may also be that the tip contains the flower buds and hence it is important for the plant to protect the genes in these cells from UV damage. This result indicates that the waste stream from processing may not contain sufficient antioxidant activity to warrant extraction of a nutraceutical.

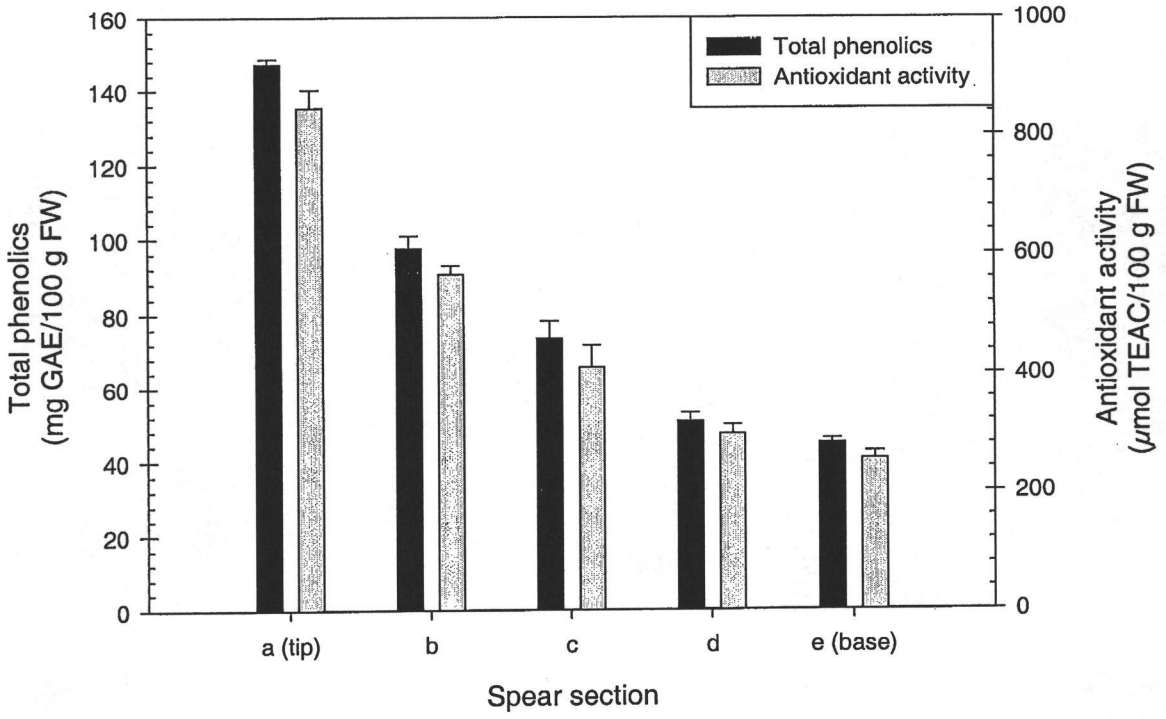

Figure 7: Distribution of total phenolics and antioxidant activity within the above ground spear of the cultivar UC 157.

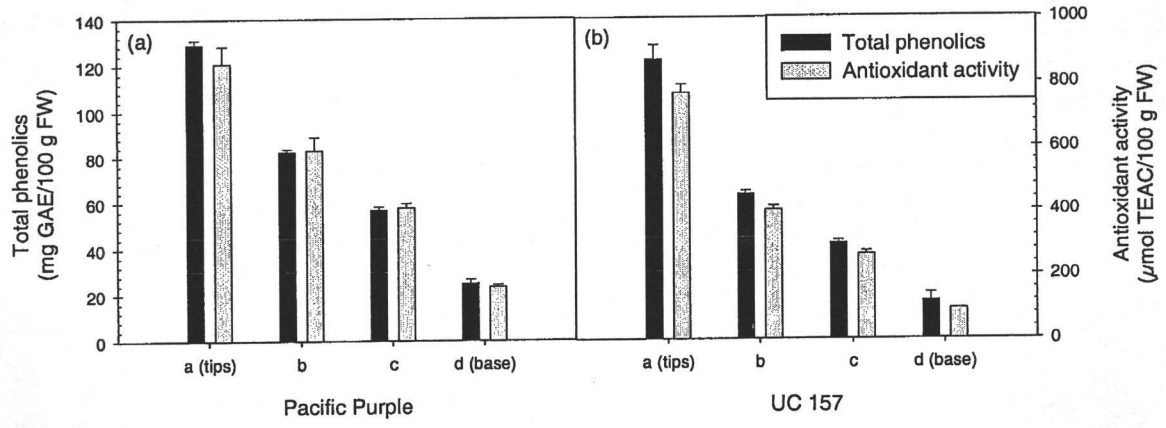

Figure 8: Distribution of phenolics and antioxidant activity along the spear, including below ground portion, for two asparagus cultivars.

4.6 Effect of cooking

There was a small drop in both antioxidant activity and total phenolic content with cooking by steaming (Figure 9), but this was not significant. A fairly recent paper by Makris and Rossiter (2001) reported a loss of 43.9% of rutin (the main phenolic in asparagus) on boiling asparagus for 60 minutes. It was observed that boiling extracted a considerable proportion of the rutin into the cooking water. This may be high because phenolics are located in outer

layers of the spear (see section 4.2). Makris and Rossiter (2001) also observed loss of antioxidant activity with boiling, and this would relate to loss of rutin. There are two reasons for major differences between our findings and those of Makris and Rossiter (2001). Firstly we steamed the spears rather than boiled and steaming would not result in the leaching of phenolics from the spear as boiling water does. Secondly, the length of time for which the samples were cooked could also have a major bearing on phenolic content and antioxidant activity. We cooked the spears until tender (approximately 10 minutes) whereas Makris and Rossiter (2001) cooked spears for an extended period only (60 min), which is far longer than anybody would normally cook asparagus. Further experiments with different cooking methods and times are required to fully investigate the effects. However, it would appear that steaming is preferable to boiling and typical cooking time does not result in significant loss of antioxidant activity.

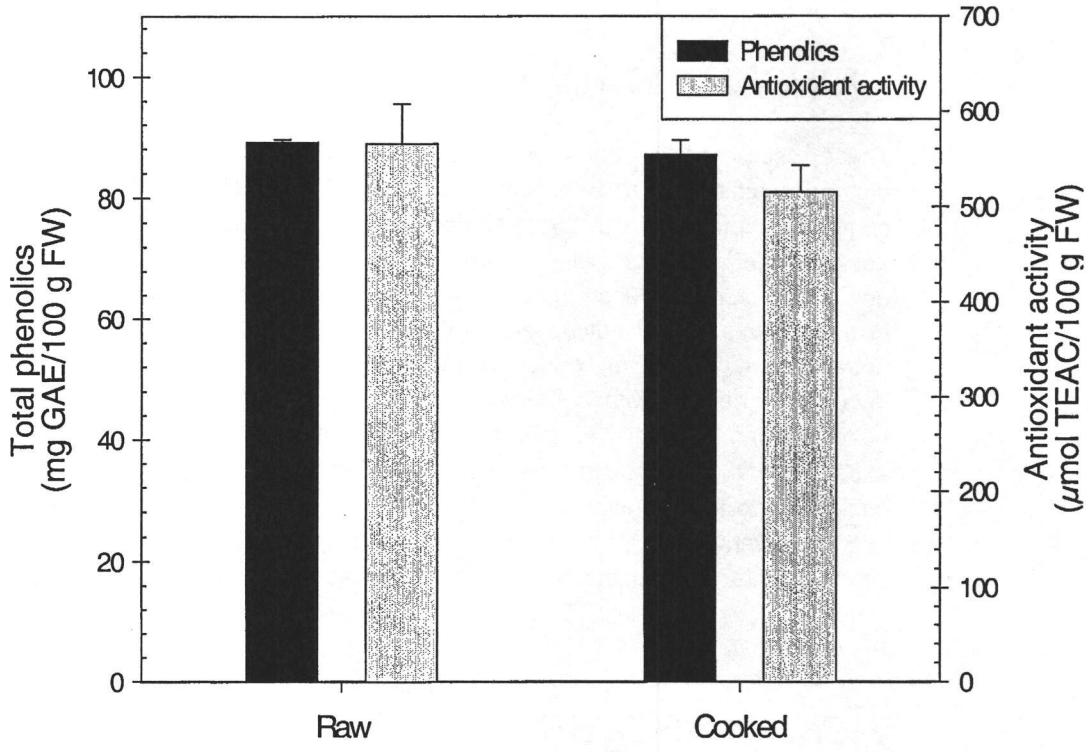

Figure 9: Effect of cooking on total phenolic content and antioxidant activity of asparagus.

4.7 Phase 2 enzyme induction

For the three cultivars examined all showed some induction of phase 2 enzymes, in the order: Jersey Giant > Pacific Purple > Taramea. However, activity was not exceptionally high being about one tenth that of typical broccoli, but better than non-cruciferous vegetables (for which most show no activity). It is interesting that these cultivars showed the same trend with phase 2 enzyme induction as they did for antioxidant activity by the ABTS assay (which is a measure of radical scavenging ability). This may just be coincidence as it may be sulfur compounds which are responsible for the phase 2 enzyme induction activity not rutin (the primary free radical

scavenger). It has recently been reported that asparagus contains a sulfur-containing tricyclic compound (aminomethylcysteine ketimine decarboxylated dimer) with antioxidant activity (Macone et al. 2002). Levels are probably quite low compared to rutin (although paper details are not available yet, only the abstract) but this may be work further investigation.

One interesting finding was a significant increase in protein levels, which paralleled increase in QR levels with increasing extract dose rate (decrease indicates cytotoxicity). The extent of this trend was unusual among vegetables we have studied; in most cases little or no increase in protein is observed with increasing dose rates. There may be a number of explanations for this including increased cell proliferation, increased protein production in cells or other enzymes also being switched on. Further investigation is required.

5 Conclusions & future research

These results back up our findings from 2000/01 that asparagus is a good dietary source of antioxidants, even when cooked (at least by steaming). The compounds present in asparagus may also have other modes of action besides free radical scavenging ability (the measure we have used for antioxidant activity). Since the base of the asparagus spear is relatively low in antioxidants it may not be an ideal starting material for extraction of a nutraceutical. However, based on our findings that spear diameter is inversely correlated with antioxidant activity, reject thin spears may be a better starting material. Further investigation may be warranted to look at extraction of the critical components and possible delivery mechanisms. This could include incorporation of asparagus powder into functional foods, e.g. snacks, beverages. This may present some challenges, such as overcoming sensory characteristics, in making those foods acceptable to consumers.

6 Acknowledgements

Thank you to Peter Falloon, Tender Tips and Penny and Diane Turpin for collection of asparagus samples. Technical assistance was also provided by Sarah Molyneux (for ABTS and phenolics assays) and Paula Wilson (Phase 2 enzyme induction work).

7 References

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Appendix

Table A1: Sample details, levels of total phenolics and antioxidant activity in asparagus samples

				Spear characteristics			Antioxidant composition	
Cultivar	Code	Sample description	Source [a]	Dry matter (%)	Average length (mm)	Average diameter (mm)	Average weight (g)	Total phenolics[b]	Antioxidant activity[c]
Cultivar variation									
Crop & Food B	1		Linc	8.85	176	10.25	11.49	95.52 ± 3.53	566.73 ± 17.61
Jersey Giant	2		Linc	8.73	189	10.73	12.31	96.18 ± 1.175	581.36 ± 28.03
Jersey Giant	3		PF	9.18	180	10.88	13.15	103.58 ± 3.95	621.99 ± 21.14
JWC1	4		PF	9.50	177	9.25	8.89	124.93 ± 1.15	724.22 ± 26.70
Pacific 2000	5		PF	8.83	179	10.50	11.10	96.44 ± 3.04	550.35 ± 35.00
Pacific Purple	6		PF	7.96	199	11.25	15.26	93.10 ± 4.42	554.00 ± 22.04
Taramea	7		TT	7.86	176	12.50	16.10	73.37 ± 2.91	449.27 ± 16.53
UC157	8		Linc	8.55	183	10.64	11.65	86.83 ± 0.39	522.13 ± 20.40
UC157	9		PF	8.83	176	9.88	10.61	102.02 ± 3.53	603.67 ± 23.45
Average								96.89	574.86

Size									
JWC1	10	thin	PF	9.89	160	7.00	4.36	150.84 ± 2.21	831.45 ± 50.36
JWC1	11	medium	PF	9.37	160	9.50	7.68	126.46 ± 0.52	691.43 ± 35.69
JWC1	12	thick	PF	8.94	160	14.00	15.67	92.71 ± 0.46	522.49 ± 24.27
Pacific Purple	13	thin	PF	7.97	160	9.50	8.60	114.24 ± 3.80	646.62 ± 30.51
Pacific Purple	14	thick	PF	8.76	160	15.00	24.60	91.48 ± 0.81	507.16 ± 18.40
Taramea	15	thin	TT	8.38	160	9.00	7.76	97.51 ± 1.73	561.81 ± 17.03
Taramea	16	medium	TT	8.06	160	12.50	14.14	77.39 ± 3.35	443.24 ± 14.50
Taramea	17	thick	TT	8.00	160	16	19.65	73.28 ± 1.61	411.48 ± 10.37
UC157	18	thin	PF	8.85	160	8.50	7.10	113.12 ± 4.84	655.23 ± 29.94
UC157	19	medium	PF	8.83	160	11.00	15.52	90.72 ± 1.18	506.78 ± 27.13
UC157	20	thick	PF	8.42	160	13.00	12.26	79.88 ± 2.46	472.59 ± 19.78

Distribution									
UC157	21	tips (5cm)	PF	11.84	250	12.00	19.91	147.23 ± 1.40	845.60 ± 30.21
UC157	22	next 5 cm	PF	9.01	"	"	"	97.36 ± 3.37	565.23 ± 14.75
UC157	23	next 5 cm	PF	7.76	"	"	"	73.55 ± 4.58	410.14 ± 37.69
UC157	24	next 5 cm	PF	7.21	"	"	"	50.63 ± 2.41	295.52 ± 14.94
UC157	25	next 5 cm	PF	7.83	"	"	"	44.77 ± 1.20	252.99 ± 12.53
Pacific Purple	26	tips	PF	11.01	355	13.00	33.63	128.95 ± 1.74	690.07 ± 42.39
Pacific Purple	27	next 10 cm	PF	8.35	"	"	"	82.46 ± 1.33	474.51 ± 33.47
Pacific Purple	28	next 10 cm	PF	8.90	"	"	"	56.81 ± 1.15	329.21 ± 11.04
Pacific Purple	29	white bottom	PF	9.94	"	"	"	25.03 ± 1.93	134.27 ± 5.47
UC157	30	tips	PF	11.23	330	12.00	26.08	139.20 ± 4.30	767.55 ± 26.66
UC157	31	next 10 cm	PF	8.43	"	"	"	72.00 ± 1.40	399.10 ± 13.04
UC157	32	next 10 cm	PF	9.54	"	"	"	47.28 ± 1.40	262.60 ± 9.42
UC157	33	white bottom	PF	10.70	"	"	"	18.62 ± 7.11	92.39 ± 1.26
Cooking									
Mixed	34	raw	Linc	8.99	183	11.66	11.95	89.15 ± 0.48	565.68 ± 41.97
Mixed	35	cooked	Linc	8.89	186	11.34	11.17	87.03 ± 2.46	514.63 ± 27.86

[a] PF=Peter Falloon, Christchurch; Linc=Crop & Food Research, Lincoln; TT=Tender Tips, North Island
[b] total phenolics expressed in mg GAE/100 g FW ± standard deviation
[c] antioxidant activity expressed in μmol TEAC/100 g FW ± standard deviation

Pacific Purple	29	white bottom	PF	9.94	"	"	"	25.03 ± 1.93	134.27 ± 5.47
UC157	30	tips	PF	11.23	330	12.00	26.08	139.20 ± 4.30	767.55 ± 26.66
UC157	31	next 10 cm	PF	8.43	"	"	"	72.00 ± 1.40	399.10 ± 13.04
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