Antioxidant levels in frozen and processed lingonberries (*Vaccinium vitis-idaea* subsp. *minus)* and bog blueberries (*Vaccinium uliginosum)*

Patricia S. Holloway[1] and Roxie Rodgers Dinstel[2]

[1]Department of Plant, Animal and Soil Sciences

[2] Cooperative Extension Service

University of Alaska Fairbanks, Fairbanks, Alaska

Introduction

Bog blueberries (*Vaccinium uliginosum* L.) and lingonberries (*V. vitis-idaea* L. subsp. *minus* (Lodd.)Hult.) are the most important wild-collected berries in Alaska. They are excellent sources of antioxidants; frozen bog blueberries have a water soluble ORAC (optical radical absorbance capacity) averaging 79 µmol TE/g, and lingonberries average 224 µmol TE/g from wild harvested Alaska fruit (Leiner *et al.* in press). Both wild berries have a tart flavor and are rarely eaten fresh. They are processed into jams jellies and other frozen, dried and cooked products.

Since the 1950s, the Alaska Cooperative Extension Service has conducted research into Alaska's wild berries including testing many recipes for private and commercial berry pickers and consumers(Stanek & Butcher 1998). Early work identified mineral nutrient and vitamin C content of these berries (Cooperative Extension Service 1950, Heller & Scott 1961), but because of recent research on antioxidants and other phytochemicals, Alaskans are interested in learning about potential health benefits of processed wild berry products. What happens to antioxidant levels when berries are frozen, cooked or dried? How can berries be preserved to maintain the most phytochemicals? The purpose of this research was to test bog blueberries and lingonberries for antioxidants and demonstrate how antioxidant levels change with recommended processing methods.

Methods

Wild berries were harvested through July and August 2005, and all samples were combined, frozen to 0 C until processing two months later. Berries were randomly divided into three replicate blocks (three processing dates), then randomly sampled to provide sufficient berries for each recipe. Nine recipes were tested for bog blueberry and eight for lingonberry:

Recipe	Berries (g)	Water (ml)	Sugar (g)	Pectin	Lemon juice (ml)	Processing method
Frozen	460					Freezer bags, air expelled, 0°C
Dried	460					Dehydrator 8h, 60°C (140°F)
Syrup	1840	187	807			Fruit mixed with sugar held at room temperature 24h, Mixture & water boiled 20min, forced through cheesecloth sieve,15min boiling water bath (b.w.b.)
Sauce	920	125	606			Boiled 20min, 15min b.w.b
Leather	920		50			Pureed with sugar then dehydrated 6h, 60°C (140°F)
Jelly	1301 ml juice		1656	89 ml liq		Berries, sugar, lemon simmered 5min, pectin added, b.w.b. 15 min
Jam	1035		1411	177 ml liq	31	Simmered 5 min, add pectin, b.w.b. 15 min
Freezer jam	690	250	1009	49g pdr		Crush fruit & sugar mixed, 21°C for 20min, pectin added, boil 1min, room temp 24h, 0°C

All samples were analyzed at Brunzwick Laboratories, Wareham MA. The scavenging capacity of water soluble antioxidants (H-ORAC$_{FI}$) and total phenolics, anthocyanins, vitamin C, p-Coumaric acid, and quercetin were analysed by methods outlined in Wada and Ou (2002). Individual antioxidants were chosen because of their high levels in lingonberries and blueberries from previous studies (Hakkinen 2000, Zheng & Wang 2003, Wang *et al*. 2005). Three, completely randomized replicates were analyzed by ANOVA, and means of processed products were compared to the control (frozen) using Dunnett's mean separation.

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Figure 1. H-ORAC$_{FI}$ levels in bog blueberry frozen and processed fruit

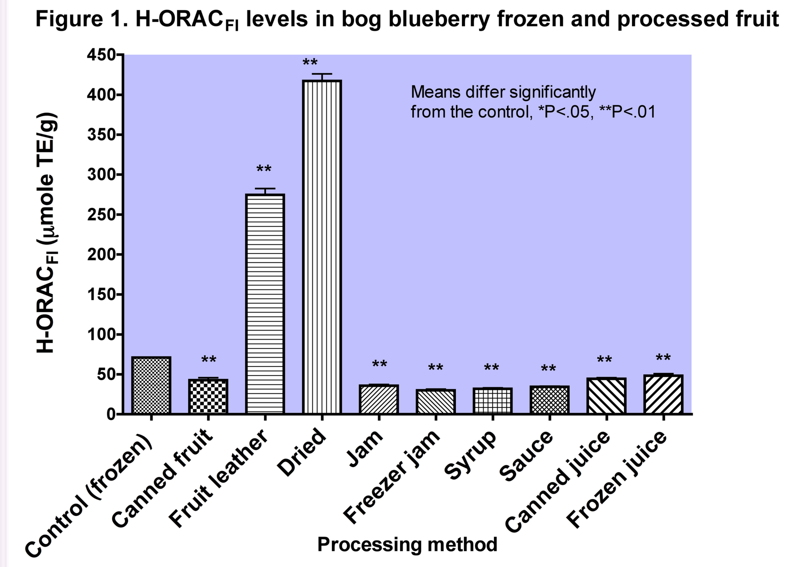
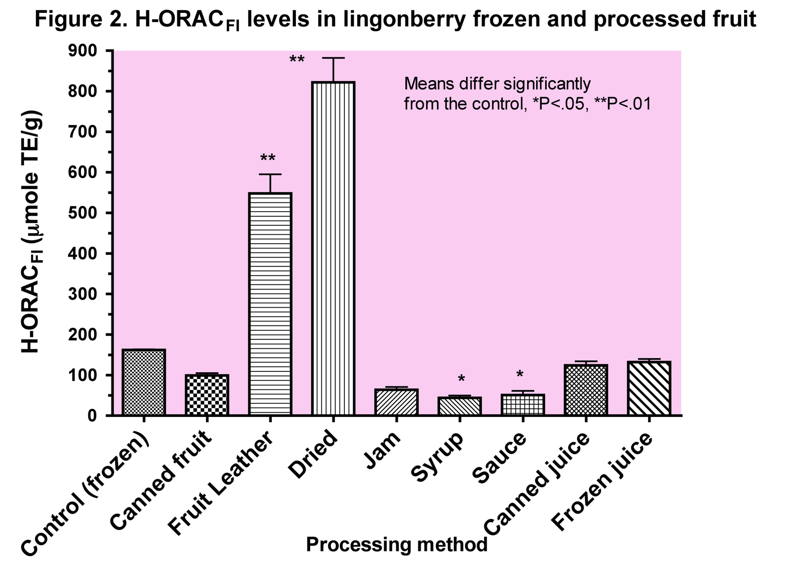


Figure 2. H-ORAC$_{FI}$ levels in lingonberry frozen and processed fruit



Hydrophilic Oxygen Radical Absorption Capacity (H-ORAC$_{FI}$)

In bog blueberry, the total water soluble antioxidant activity (H-ORAC$_{FI}$) level in all processed products was significantly lower than the control except for dried fruit and fruit leather in which the antioxidants were concentrated by moisture removal (Fig 1). This same trend occurred in lingonberry fruit leather and dried fruit (Fig. 2). Although all processed lingonberry products had lower H-ORAC$_{FI}$ levels than the control, canned fruit and canned and frozen juice did not differ significantly from frozen berries.

Total Phenolics

Total phenolics increased significantly with drying and processing as fruit leather in both bog blueberry and lingonberry (Figs 3 & 4) but were lower than the control with most other methods of processing. Only canned and frozen juice showed no decrease in total phenolics from the frozen berries for both species.

Figure 3. Total phenolics (mg gallic acid equivalents per g) in bog blueberry frozen and processed fruit

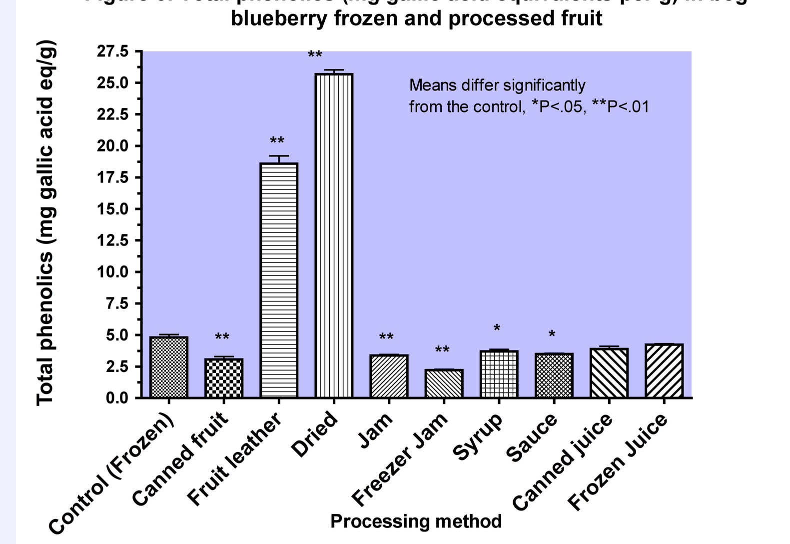


Figure 4. Total phenolics (mg gallic acid equivalents per g) in lingonberry frozen and processed fruit

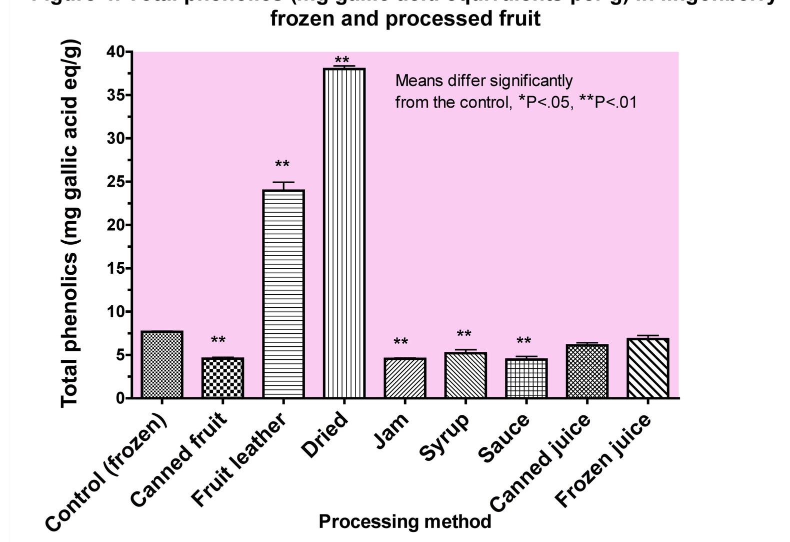


Figure 5. Total anthocyanins (mg cyanidine-3-glucoside equivalents per g) in bog blueberry frozen and processed fruit

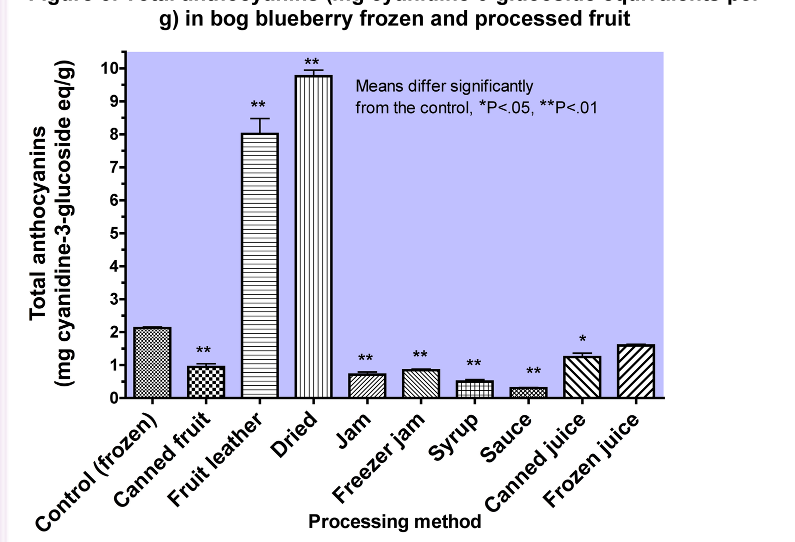
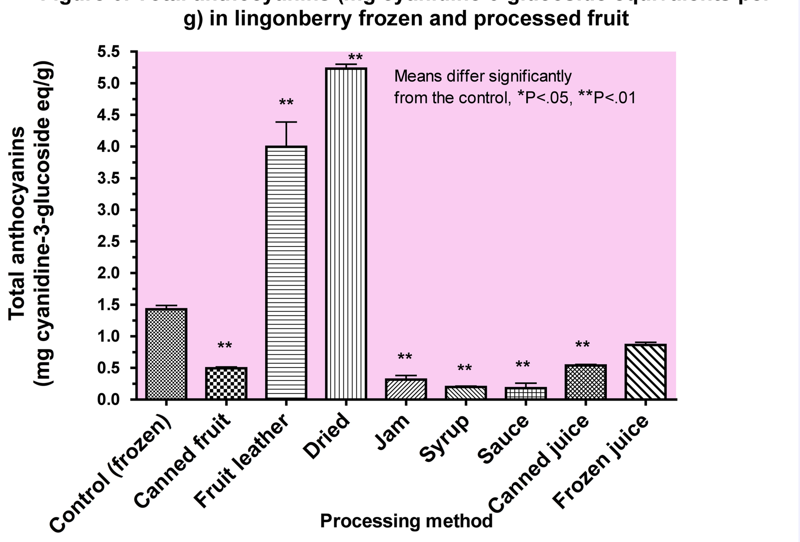


Figure 6. Total anthocyanins (mg cyanidine-3-glucoside equivalents per g) in lingonberry frozen and processed fruit



Total Anthocyanins

Total anthocyanins increased significantly with drying and preservation as fruit leather for both bog blueberries and lingonberries (Figs 5 & 6). but decreased with most other methods of processing. Only frozen juice showed no decrease in total anthocyanins from the frozen berries.

Quercetin

Quercetin levels in bog blueberries were significantly higher than frozen berries for all methods of processing except freezer jam and frozen juice (Fig 7). Quercetin levels increased by three or more times the control in all products that were not frozen. A similar trend did not occur in lingonberries where nearly all methods of processing showed decreases in levels of quercetin except fruit leather, dried fruit and frozen juice (Fig 8).

Figure 7. Quercetin levels in bog blueberry frozen and processed fruit

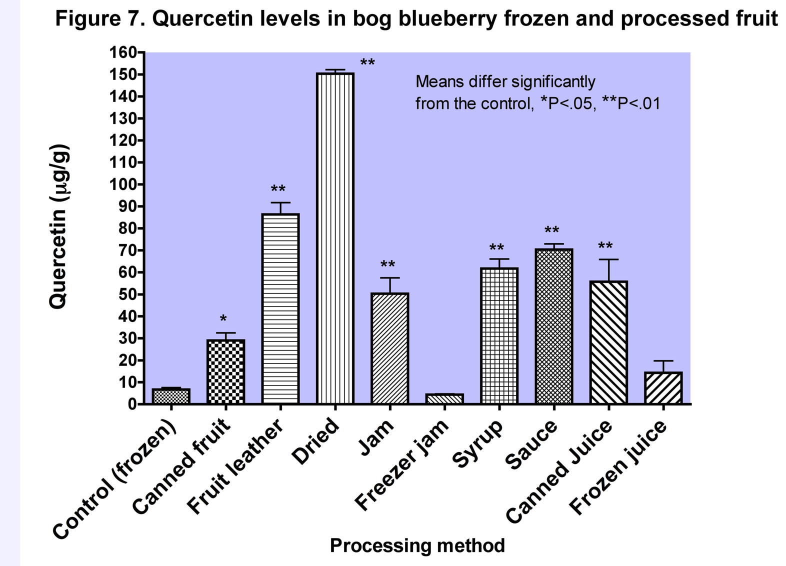


Figure 8. Quercetin levels in lingonberry frozen and processed fruit

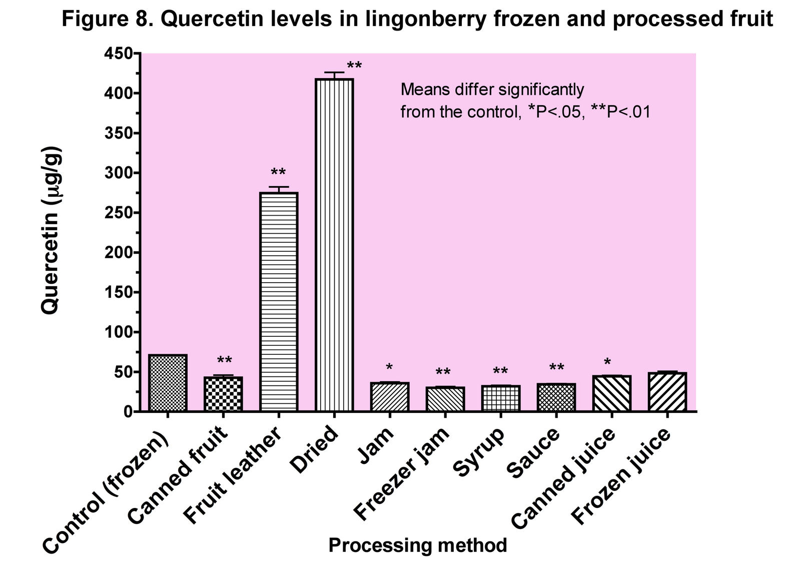


Figure 9. Vitamin C levels in bog blueberry frozen and processed fruit

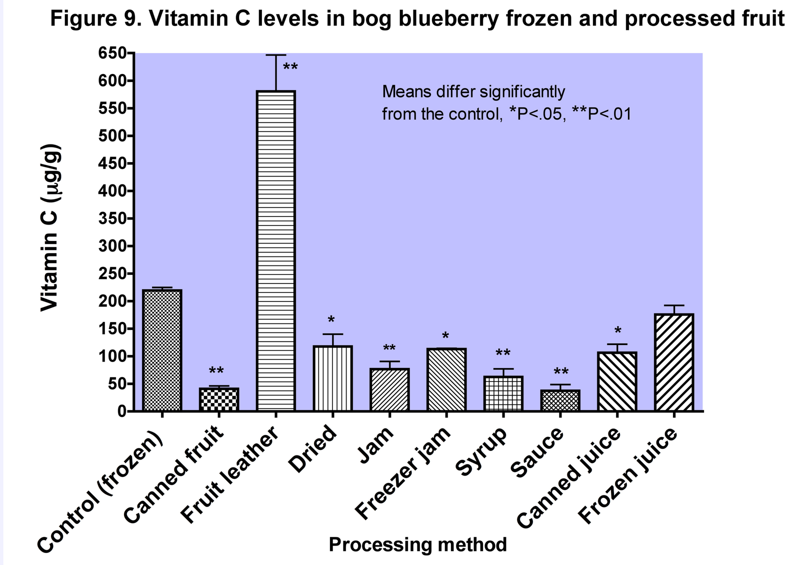
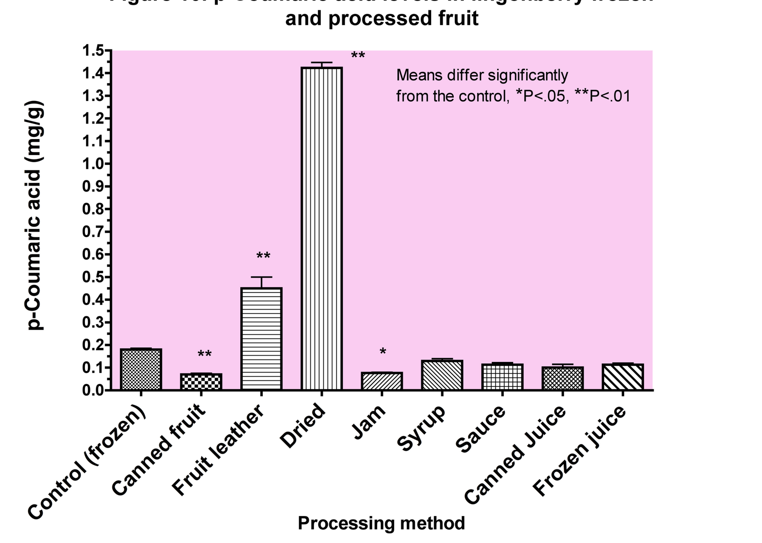


Figure 10. p-Coumaric acid levels in lingonberry frozen and processed fruit



Vitamin C and p-Coumaric Acid

Vitamin C levels were negligible in all samples of lingonberry. Bog blueberry fruit leather had higher vitamin C activity than frozen berries but in nearly all other processing methods, it was lower (Fig 9). Only frozen juice had similar levels of vitamin C to the frozen berries.

p-Coumaric acid levels were negligible in bog blueberry including frozen berries. Levels in lingonberry were significantly higher in fruit leather and dried fruit and lower in canned fruit and jam (Fig. 10). The other methods showed reduced levels but were not significantly different from the frozen berry control.

Conclusion

Changes in antioxidant levels with processing may be due to:

a) Drying that concentrates antioxidants in the skin (Haakinen 2000)
b) Dilution from added sugars and water per gram of product
c) Oxygen degradation of antioxidants i.e. vitamin C (Gill *et al.* 1999)
d) Biochemical changes in antioxidants to non-reactive substances or new compounds with antioxidant activity (Nicoli *et al.* 1997)
e) thermal instability due to high or low temperatures during storage and processing (Davey *et al.* 2000, Gahler *et al.* 2003, Haakinen 2000, Kalt *et al* 2000, Nicoli 2001,Piga *et al.* 2003, Zafrilla *et al* 2001,
f) Removal of skin, etc. that are high in antioxidants (Rothe 2005).

Researchers have shown that antioxidant levels change with time in processed products and frozen berries (Zafrilla et al. 2001, Haakinen 2000), so we do not know the "shelf life" of our products. Nevertheless, we can conclude that the antioxidants we tested are not totally destroyed with processing; even boiled products have significant levels of antioxidants.

Dried fruit and fruit leather provide the greatest levels of antioxidants in processed products including quercetin, p-coumaric acid, total phenolics and anthocyanins, and vitamin C.