**TITLE:**
Nutritional Quality of Organic Fruits: Influence of processing on phenolic compounds, anthocyanins, and antioxidant activity in organically and conventionally grown raspberry and blueberry fruits

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**KEY WORDS:**
Agricultural production system, blueberries, canning, dehydration, freezing, phytochemicals, puree processing, red raspberries

**ABSTRACT**
Consumer demand for organic foods is increasing and the preference for organic food is associated with multiple factors that, in general, reflect an increased interest towards personal health, animal welfare, and environmental protection due to the absence of contaminants in the production process. A significant portion of organic produce needs to be processed in order to make them available throughout the year. Sometimes, processed fruits are desirable as ingredients in bakery and dairy products. During the last decade, organic farm acreage in the state of Washington has increased. The demand for safe processing of organic produce is also increasing. The long-term goal of the proposed research is to improve the shelf life and nutrient retention in organically grown fruits by increasing our understanding of the mechanisms of nutrient destruction by processing methods. The specific objectives of the proposed research are to study the influence of common postharvest processing and storage methods on the retention and bioavailability of phytochemicals in organic and conventional red raspberry and blueberry fruits. The proposed research is relevant to the BioAg program and CSANR's mission that promotes sustainable and organic agriculture.

**RESULTS**
The phytochemical contents of mechanically harvested organic red raspberries were higher than those harvested by hand. Duke blueberries contained higher level of phytochemicals than Reka blueberries. The phytochemical content and antioxidant activity in fresh red raspberries and blueberries were not consistently influenced by the agricultural production system, that is, organic or conventional methods. Thermal treatments and dehydration caused significant changes in phytochemical contents in both conventionally and organically grown berries. The phenolic contents and antioxidant activities in berries increased while total anthocyanins decreased due to canning. The puree/juice obtained from blanched blueberries retained higher levels of total anthocyanins, phenolics, and antioxidant activity due to the positive effects of this thermal treatment. The higher recovery of phenolic compounds resulted in a significant increase in antioxidant activity of the blueberry puree/juice. The addition of a blanching step prior to blueberry processing should be considered an important step for enhancing the health benefits of blueberry purees and juices.

**PROJECT DESCRIPTION**
National and global organic sectors are growing significantly due to increased consumer demands for organic foods. In the USA, the market for organic foods has increased significantly, and at the end of 2007 it was estimated to be worth over $15 billion. Many surveys of consumer attitudes and characteristics are conducted to identify the reasons for this increased trend. The preference for organic
food is associated with multiple factors that, in general, reflect an increased interest towards personal health, animal welfare, and environmental protection due to the absence of contaminants in the production process. There is currently an acute shortage of organic ingredients for intermediary handlers to add to processed foods that sold in the organic sector. Increasing the opportunity to supply organic berries to the food processing industry is one of the main goals of our study.

The biosynthesis of phenolic compounds in plants is correlated with decreased damage from insect pests and pathogens, as well as from UV radiation, suggesting the protective role of these compounds. Organically grown produce may generate higher levels of phenolic compounds in response to insects and diseases, and therefore be more healthful. Many studies comparing the nutritional quality of organically and conventionally grown fruits and vegetables in terms of macronutrients, vitamins, minerals, and phytochemicals have been published. Several articles have presented critical reviews of results from published studies comparing the influence of organic and conventional production systems on phytochemical contents in fruits and vegetables. The overall evidence seems to favor enhancement of phytochemical content in organically grown produce, but there has been little systematic study of the salient factors contributing to this apparent increase. Given several limitations in the majority of published studies, further research is necessary to elucidate the factors that may or may not contribute to enhanced phytochemical contents of organic produce.

The availability of fresh conventional and organic fruits and vegetables in temperate zones is limited during the winter months due to reduced agricultural production in these latitudes. Some fruits and vegetables can be easily shipped from other regions of the world, but others, like berries, are highly perishable. Hence, some sort of processing, such as canning, freezing, juice processing or drying, is required to extend their shelf life. Processing/preservation methods invariably influence nutritional quality of fresh produce. Normal cooking at temperatures of 75-100°C for 10-30min was shown to affect phenolic content as well as anti-radical and anti-proliferative activities of juice in the majority of vegetables. During jam processing, the total anthocyanin content per gram of fruit was reduced by 20 and 40% for ‘Heritage’ and ‘Zeva’ red raspberries, respectively. Few studies have monitored the effects of post-harvest storage and processing on the phytochemical contents of organically versus conventionally grown fruits and vegetables. There is a need to understand the mechanisms of degradation of phytochemicals in organic fruits and vegetables during common processing operations. The information on stability of these health-promoting components during processing will be useful to the organic food processing industry in maintaining important nutritional attributes of these products.

The consumption of berry products is encouraged worldwide because of their possible health benefits. Red raspberries and blueberries contain high amounts of anthocyanins and other phenolic compounds, and thus have significant antioxidant activity. Berries are often processed into juice, juice concentrate or canned, dried or frozen for subsequent use in beverages, syrups or other products. However, various factors during the processing of berries may degrade anthocyanins, phenolic compounds, and other antioxidants. Blanching of fruits before thermal processing has shown to increase the radical-scavenging activity of the processed fruits due to higher recovery of anthocyanin pigments and phenolics. Due to their possible beneficial roles as nutrients in food, it is critical that changes in anthocyanins, phenolic contents, and antioxidant activity during processing and manufacture be measured to better assess the dietary value of the processed products. The objectives of this investigation were to evaluate the effects of common processing by canning, juice processing, freezing and drying on anthocyanins, phenolic contents, and antioxidant activity of conventionally and organically grown red raspberries and blueberries.
**OUTPUTS**

- **Work Completed:**
  Established multi-disciplinary research team from food processing, pharmaceutical and horticultural sciences; conducted experiments at 3 different WSU facilities for nutritional and functional analysis; information was shared at national conferences; 1 article is in review and another in preparation for publication.

- **Publications, Handouts, Other Text & Web Products:**

- **Outreach & Education Activities:**
The findings of this study was shared with 38 berry processors and producers in Washington State, who were asked to participate in an online survey to determine how they are currently marketing the nutritional properties of their products, and if the result of the research would affect their marketing or production strategies. The findings of our study were new information for 80% of respondents, and deemed important by all respondents. It was clear from the survey results and from the widespread use of nutritional messaging that the Berry industry believes in the efficacy of marketing their products as “functional food”.

**IMPACTS**

- **Short-Term:** The project generated scientific information on the phytochemicals in organic and conventional raspberries and blueberries and the stability of these phytonutrient during common processing methods. The broader impact of this research methodology can be applied to other preservation methods and a variety of other organic produce, with minimal modification to the basic protocol.

- **Intermediate-Term:** This information will assist the food processing industry in optimization of processing methods designed for organically produce berries, which may provide an economic incentive to organic food producers and processors. These processed organic fruit products, with a high level of phenolics and antioxidant activity can be incorporated into children’s school lunch programs.

- **Long-Term:** Increased consumption of nutrient dense processed organic foods may improve the health of citizens and significantly reduce health care costs.

**ADDITIONAL FUNDING APPLIED FOR / SECURED**
Using preliminary results of the experimental work carried out in this project, three investigators (S. S. Sablani, P. Andrews and N. Davies) participated in following grant proposals to various funding agencies. Though proposals, reviewed favorably were not funded and we plan to strengthen our proposals using additional results from the proposed work and then resubmit these proposals in the next round of competition.

• Enhancing Disease Prevention using Nutraceuticals Derived from Washington State Agriculture, Life Science Discovery Funds (LSDF), 2009; $1.5 million (PI: Shulin Chen)

GRADUATE STUDENTS FUNDED
Graduate students, Pallavi Mohekar, Sunil Kumar and Luis Bastarrachea all pursuing their Master of Science degree in the Department of Biological Systems Engineering were partially funded through this project

RECOMMENDATIONS FOR FUTURE RESEARCH
We propose to continue the interdisciplinary research effort that started in 2008 and further strengthen collaboration among the team members. The broad goal of our research program is to advance the shelf life and nutrient retention in organically grown fruits by increasing our understanding of the relationship between processing/preservation methods and nutrient degradation.

The specific objectives for Year 2 are
(1) Evaluate phytochemical contents in matched pairs of organic and conventional raspberries and blueberries for one more year. This study will help us to understand changes in phytochemical contents in berries over the years in organic farming.

(2) Quantify the retention of phytochemicals in processed organic and conventional berries during storage at various temperatures (-80, -35, -18°C for frozen; 4°C for juice/puree and 25°C for canned and dehydrated berries). This study was initiated last year and we expect to complete it this year with the help of renewal funds. The findings of this study will allow berry processors to define the shelf life of processed products based on nutritional contents.

(3) Produce red raspberry encapsulated powder with improved antioxidant stability using a spray drying technology. This will expand the market of frozen berries by providing additional opportunities to the berry processors to maximally utilize their processing facilities throughout the year using their stored frozen berries. Nutrient dense berry powders are highly desirable ingredients for dairy and bakery products.

(4) Determine concentrations of calcium, sodium, potassium, iron, zinc, and magnesium in fresh and processed conventional and organic berries. This study will provided fundamental information about differences between organic and conventional production systems which may affect mineral concentrations in berries.

(5) Determine bioavailability of flavonoids such as ellagic acid and quercetin from fresh and processed berries. This study will allow us to determine additional benefits of processed berries compared to fresh ones.

BUDGET:
SALARY/WAGES: (One semester grad student and student/non student time slip) $22,057
MATERIALS AND SUPPLIES: (Chemical, enzymes, lab supplies & maintenance) $7,928
TOTAL $29,985
BIBLIOGRAPHY: