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Value-Added Products for Fresh Highbush Blueberries[1]

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Introduction

Blueberries (*Vaccinium corymbosum* L., Ericaceae) are members of the Ericaceae family. Related small fruits include the cranberry (*Vaccinium macrocarpon* Ait.) and the lingonberry (*Vaccinium vitisidaea* L.) (Routray and Orsat 2011). The United States is the largest producer of blueberries in the world, harvesting a total of 335,600 tons of blueberries in 2014, which accounted for 60% of the world production (USDA 2015). About 60.8% were sold as fresh fruits and the rest were processed.

As production continues to grow, more blueberries are machine-harvested and processed. There is a growing need to improve traditional processing methods and develop new technologies to add value to blueberries. Freezing and drying are the most commonly used methods to preserve fresh harvested fruits or to pre-process them for use in products like baked goods, fillings, soups, topping, snacks, energy and breakfast bars, and some ready-to-eat cereals. Many traditional products such as juice, concentrations, puree, jams, wine, or canned blueberries can be made directly from fresh blueberries.

As blueberry production increases, more growers are starting to explore markets for blueberries overseas. China, India, and South Korea are expected to join the US in leading in blueberry consumption in future decades. In this paper, we review the current status of blueberry production, harvesting, post-harvest processing for foods, and market promotion in the United States and worldwide. We also summarize new blueberry applications in pet foods, beauty products, and dietary supplements.

Blueberry Production

Global blueberry production has grown significantly in the past two decades. Highbush blueberry acreage worldwide increased by an estimated 83% from 2005 to 2010, and blueberry production increased by 46.5% from 2000 to 2011 in the U.S. (E. R. S. USDA 2013). Major commercial blueberry types include *Vaccinium corymbosum* L. (highbush blueberry), *Vaccinium ashei* Reade (rabbiteye blueberry), and native *Vaccinium angustifolium* Ait. (low-bush blueberry). Over 82,630 acres of land are growing cultivated blueberries with an estimated annual production of 283,400 tons (USDA 2015). The second major blueberry cultivar is the lowbush species, which mostly grows in Maine and provinces of eastern Canada with an annual production ranging from 40,000 to 55,000 tons. The state of Georgia produces nearly 50% (1,500 ha) of rabbiteye blueberries. The total national annual production of rabbiteye is estimated at 5,500 tons. The states of Minnesota and Michigan grow primarily half-high blueberries, which occupy a few hundred hectares. Florida and the lower Gulf Coast states produce southern highbush (*Vaccinium* hybrid), which are similar to highbush but are adapted to low-chill climates. Generally, fresh blueberry season starts in April and ends in early October and most frozen blueberries are produced between June and August.

Because profit margins are highest for fresh blueberries, most blueberries are produced for the fresh market, and the

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rest are processed into various foods or ingredients. Hand harvesting is recommended for berries sold on the fresh market, while processed blueberries, mostly for the frozen market, are machine harvested (Strik 2006). Blueberries sold on the fresh market must have good individual integrity and quality. Thus, hand harvesting, albeit labor intensive, is necessary to avoid fruit damage. Machine harvesting has the advantage of high efficiency and low cost. However, up to 78% of the mechanically harvested highbush blueberries are bruised and cannot be sold on the fresh market (Brown et al. 1996). Thus, some breeders have newly developed "firm-textured" highbush blueberries, which are much more resistant to bruising (Padley 2005). University of Florida breeders have developed cultivars with firm fruit such as 'Sweetcrisp', 'Farthing', and 'Meadowlark' that may have potential for machine harvest (Williamson, Olmstead, England, and Lyrene 2014).

Figure 1. High-bush blueberries grown in Florida.
Credits: Liwei Gu

Blueberry Processing Technologies and Products

Frozen Blueberries

Although most blueberries are sold as fresh fruits, processed blueberries or blueberry-based ingredients are very popular in the food industry. Frozen blueberries are the major processed products and meet the demand year round. Freezing maintains freshness, good flavor, texture, and color. In 2012, out of 181 million pounds of processed blueberries, 56.5% were frozen berries. The per capita annual consumption of frozen blueberries in the U.S. was 0.45 lb.

Individually quick frozen (IQF) is the most widely used freezing method because it maintains the characteristics and identity of fresh fruit. The pre-treatment facilities for IQF berries include a multilayer shaker dock, a series of pans with water to clean the berries, and water spray with chlorine (20–35 ppm) for sanitization. The berries are frozen in a tunnel with high-velocity cold air (-40°F for 10 minutes). Frozen berries are inspected for defects and stored in poly consumer packs for sale.

Block frozen blueberries are another type of frozen processed product. The advantage of block frozen is its high cost efficiency since the process can be done for a large quantity of fruits in cartons. The suitable applications for the block frozen blueberries include toppings, syrup fillings, jams, preserves, soups, and some other applications in which individual fruit quality is not important. In addition, there is an increasing demand for infused frozen blueberries in the bakery industry. Berries are infused with sweeteners, usually sugar, to a Brix of 25–40 and then pasteurized and frozen. The moisture content of these sugar-infused blueberries ranges from 10 to 50% by weight (USHBC 2014).

Dried Blueberries

To extend shelf-life, blueberries can be dried to a moisture content of 11 to 18% from fresh or frozen fruits. Dried blueberries are stable under cool and dry storage conditions. Berries can also be sweetened by infusing them with sugars or syrup and air-drying them to a moisture content of 8 to 14%. Infused-dried processing maintains more fresh-like texture, color, and flavor than berries dried by hot air. The infused-dried berries are widely used in snacks, breakfast and energy bars, and some ready-to-eat cereals.

Freeze-dried blueberries have found increasing applications in some ready-to-eat cereal products. The principle of freeze-drying is the direct conversion of ice to gas under high vacuum. Freeze-drying gives favorable attributes to blueberries such as light weight, crispy texture, low bulk density, and low water activity. It also preserves important nutraceuticals such as anthocyanins and phenolics. IQF blueberries are used in the production of freeze-dried blueberries. However, freeze-drying is a time consuming and expensive process (3 to 5 times more costly than other drying methods), which limits its usage in the food industry (USHBC 2014).

Blueberry Juice

Blueberry juice is a popular value-added product for a niche market. Blueberry juices are considered a healthy beverage due to their high phytochemical content. Juices possess some ideal characteristics such as their dominating flavor, ideal color for blending, and seeds that are easy to separate during juicing. However, juices can be expensive

because high demand and high price of berries for the fresh market leaves fewer berries are available for juice production.

Both fresh and frozen berries can be used for blueberry juice production. The general steps include the separation of juice from pomace with a screw expresser, followed by clarification using bentonite and gelatin, filtration, and pasteurization (85°C; 90 seconds). The final single-strength blueberry juice usually has Brix of 8 to 12 while the blueberry juice concentrate has Brix of 45 to 65. Juice pressing methods have effects on the color and flavor of final products. For example, cold press extracted blueberry juice has a light blue color and delicate flavor while hot press juice with enzyme treatment produces juice with a dark purple-blue color and stronger flavor.

Blueberry Wine

Blueberry wine is a unique product with a complex taste combination of sweet and tart. It is also popular because of its significantly higher antioxidant activity when compared to many other wine products (Saucier and Waterhouse 1999). Phytochemicals, including anthocyanins, flavonoids, and catechins, are effectively transferred from the juice, skins, or seeds into the wine during fermentation (Su and Chien 2007).

Usually, blueberry wine is produced by two-step fermentation. In the first week, blueberries with skin and seeds intact are lightly crushed and transferred into tanks containing sulfur dioxide and pectin enzymes. This step is critical for the wine clarifying process since the naturally present pectin needs to be removed prior to fixing the alcohol. In the next two to three weeks, berries are further fermented to produce alcohol with the aid of yeast and added sugar. Then the wine is collected on a free run basis from the dregs, and remaining wine juice can be extracted by lightly pressing the residual. After that, the wine may be stored in American oak barrels for aging to produce the full-bodied wine or is further clarified and transferred into bottles for the sweeter wines.

Blueberry Puree and Cans

Blueberry puree is suitable for use in sauces and fillings. The general processing steps are crushing the berries, passing through a pulper/finisher, pasteurizing, cold filling, and freezing for storage. Blueberry puree is mostly used to make bakery fillings after adding sweeteners and stabilizers according to the requirements of the final products. Canned blueberries are also available on the market. Light or heavy syrup and water may be added to pack blueberries in cans. The standard procedure for canning is 93–95°C (200–203°F) for 25–30 minutes.

Blueberry Nutraceuticals as Dietary Supplement

Fresh blueberries are known to have a higher antioxidant capacity than other fruits. Phytochemicals from blueberries are shown to prevent body weight gain, lower blood cholesterol, and prevent cancers. A portion of harvested blueberries are not suitable for fresh or frozen products due to size, color, or bruising. These berries can be used to produce concentrated, calorie-free, sugar-free nutraceuticals to be used as a dietary supplement. The blueberries are crushed and extracted with hot water. The water extract is loaded into a column packed with food grade adsorption resin. After loading, sugars in the extract are washed away using water. Adsorbed nutraceuticals are recovered by 50% alcohol. Alcohol is evaporated to yield sugar-free nutraceutical extract. The extract has a much higher content of antioxidants and disease-preventing nutraceuticals than fresh berries (Buran et al. 2014). Its bioactivity is 70% that of aminoguanidine, a drug candidate for treating diabetic complications (Wang et al. 2011). This unique product is intended to be used as an antiglycation dietary supplement for the 8.3% of the United States population suffering from diabetes, and the additional 35% of the US population that has impaired glucose tolerance, classified as pre-diabetic (CDC 2011).

Blueberry Market and Future Marketing Strategies

The blueberry industry has enjoyed continuous growth over decades. In the US, more berries are sold for the fresh market (estimated 1.25 lb per person annually consumption) than those being processed (estimated annual consumption 1.01 lb per person). The average price for fresh and processed blueberries was $2.19/lb and $0.92/lb, respectively. Both fresh and frozen blueberries are available virtually year round. The export of blueberries has also increased along with the booming overseas demand. The major fresh export markets include Japan, Switzerland, the Netherlands, the United Kingdom, and Belgium. The major frozen markets include Japan, Australia, Korea, and Taiwan.

Because of consumers' increasing health awareness, food products made or incorporated with blueberries can advertise themselves as a source of antioxidants and fiber. Food companies are interested in developing new products with blueberries as an ingredient. In 2013, around 3,100 new blueberry-containing products were developed in Asia,

Europe, and Latin America, and about 1,000 new blueberry products were developed in the U.S. market.

Other than traditional food items, items with blueberry ingredients now include pet foods, natural cosmetics, and beauty products. Currently, the United States remains the largest producer and market of blueberry-containing pet foods. This trend, however, is spreading fast around the world, especially in China and Japan. Pet food companies promote their products by driving pet owners' perception of the health benefits of blueberries, which include antioxidants, benefits to eyesight, and urinary tract infection prevention. Dog foods containing blueberries have been on the Chinese and Japanese markets since 2014, and these regions are expected to be a fast growing pet foods market in the future. In 2013, blueberry beauty goods started a "Blue Fever" in South Korea due to the berry's proclaimed super anti-aging properties for skin care.

Conclusions

Blueberries, as one of the most popular fruits in the market, have experienced continuous growth in production, product extension, and sales worldwide. North America remains by far the major player in the blueberry fresh and processed market. Health benefits are still driving blueberry demand ahead of supply worldwide. Thus, blueberries continue to be a featured ingredient in new product development, and various processing technologies have been applied and improved for producing high quality products. Despite the market growth limitation in the US, development of novel products in overseas markets, especially China, India, and South Korea, could become the future of the blueberry industry in the coming decades.

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