Grape (*Vitis vinifera*) Seed and Skin Flours Contribute Flavor and Functionality to Baked Goods

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California wine growers crushed 3.3 million tons of grapes in 2011, resulting in 660,000 tons of pomace. Grape seeds and skins represent ≈20% of the total fresh fruit weight that enters a winery. Most pomace is sent to landfills, and the remainder is returned to farms as livestock feed or composted fertilizer. Although it is suitable for use as a natural fertilizer, it may be more valuable as a food ingredient because as much as half of the nutrient value of grapes is contained in these fruit solids.

A diet lacking fruits and vegetables that is high in processed starches, sugars, and fats generates oxidative stress and can contribute to metabolic disease. Burton-Freeman et al. (3) recently demonstrated that inclusion of fresh strawberries in a typical meal prevents oxidative damage for hours after consumption. Natural antioxidants in plants reinforce healthy digestion by preventing cell damage and inflammation caused by oxidation during metabolism of foods.

Refined grain-based foods in the Western diet are deficient in key micronutrients that aid in human gene expression and enzyme functions that can help prevent common metabolic syndromes such as diabetes (1,6,10). Micronutrients are commonly lost during processing. Fortification of grain-based products is commonly performed to replace key minerals and vitamins that are lost during processing but does not restore bioactive plant components such as organic acids, fibers, polyphenols, and prebiotic polysaccharides that are lost.

Vitamins and minerals, such as magnesium, potassium, and calcium, have been shown to aid in control of inflammation and metabolism (2). Recent work performed at the Children's Hospital Oakland Research Institute showed that grape seed and skin flours contain ideal ratios of these key micronutrients. As a result, adding grape seed or skin flours to baked goods can restore critical phytonutrients and microminerals to the diet. Functionally, they also extend product shelf life and add depth of flavor, fiber, and color to traditional baked goods.

Grape Seed and Skin Flours

Although there are only a handful of producers, grape seed and skin flours are available commercially. Processing is relatively simple: seeds and skins are separated and then dried with heat. The skins are separated from the seeds to produce a more consistent product. Varietal and regional differences affect both appearance and flavor.

Grape Skin Flour. Grape skins contain more of the organic acids, anthocyanins, and flavors that typify a fine wine's varietal character than do the seeds; however, grape skin flours are not typically produced. Commercial grape skin flour is produced from separated skins. Grape skins contain ≈24–36% dietary fiber, mostly as cellulose, which has recently been shown to have a unique organizational structure (9). The molecular structure of grape skin cellulose is made up of small spherical microcrystals, not fibers, as is found in wood or cotton. This structure provides great potential for texture options and lends itself to better incorporation and coating in mixtures. Grape skin flours also can be used to introduce more acid, mostly tartaric and malic, to help condition rapid-rise doughs.

Grape Seed Flour. Grape seed flours are made from a press cake after defatting. They are higher in dietary fiber (31–50%) than grape skin flours and contain more protein. The protein in fine wine varietal grape seeds is nearly complete and ranges in concentration from 14 to 17%. Fat is also present in grape seed flour. Depending on seed moisture, variety, and temperature, fat extraction (as grape seed oil) is typically 30–70% efficient, and some amount of polyunsaturated fat is left in the subsequent flour. Grape seed flours contain phytosterols (β-sitosterol, stigmasterol, and campesterol) that promote heart health and provitamin A forms of xanthines that promote eye health. Depending on the process used, these flours may contain up to 8% grape seed oil by weight.

Functional Attributes in Baked Goods

Gluten-free Baking. Working with grape seed and skin flours changed Master Baker Craig Ponsford's thinking about gluten-free baking. He recently formulated an award-winning series of gluten-free cookies that he says would not have been as good without the influences of the fine wine varietal flours with which he was asked to work. Over the past two years he has used these flours in artisanal breads

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and found that the flours influence the crumb and broadness of flavors obtained. Working with new formulations in his baking laboratory, he continues to discover new applications for grape seed and skin flours. He has found that the flours work best in a 1:1 combination (seed/skin), and crossing varietal barriers has produced good results. His customers also have reported back that pumpernickel and rye loafs made with grape seed and skin flours last an extra week on the kitchen counter before mold appears. The polyphenols contained in grape skins and seeds can extend shelf life. In addition, grape pomace is naturally antimicrobial and can provide useful dietary fibers when used as an adjunct in foods (12). Ponsford also has observed that the flavors continue to develop over time and staling is less of an issue.

Dough Hydration. Hydration of grape flours is different than that of typical whole wheat flours. In most formulations using grape skin or seed flours, more water is needed to achieve the desired texture. A study of Syrah grape skin flour showed that ≈30% more water is required to achieve the same wetness typically observed with whole wheat flour.

Behavior in Different Applications. Eric Frischkorn, a chef at the Kendall-Jackson Wine Center, has found that seed and skin flours behave differently in different applications. For example, pasta made with Syrah grape skin flour requires the addition of more water. Although standard yeast breads containing a 1% kitchen yeast addition aren't affected, artisan bakers who typically use indigenous yeasts and longer incubation times may have difficulty achieving the same rise. Frischkorn has found that up to 3% Chardonnay grape seed flour can be used in sourdough made with an in-house starter without causing adverse effects. In Frischkorn's experience, the most important factor influencing baking performance is the effect of grape seed flour on gas cell formation (Figs. 1 and 2). The cells tend to be more irregular and randomized, most likely due to the interaction of grape tannins with gluten. Texture does not appear to be impacted at addition levels from 1 to 5% (wt/wt).

Sensory Attributes in Baked Goods

Color Compounds. Grape seed and skin flours most commonly contribute purple and rose colors that vary in depth and hue depending on the grape variety used and the pH of the dough mixture. Red grape varieties contribute the most color, although "pinking" of baked goods containing Chardonnay and Sauvignon Blanc grape seed flours has been observed (P. Novak, *personal communication*, 2011). This pink color appears as a line in the middle of the cookie after baking and is most likely due to procyanidin compounds that oxidize with heating and leavening. Red grape skin flours (e.g., Syrah, Cabernet, Merlot, and Pinot Noir) have varying concentrations of color compounds, as well as other polyphenols. These flours have high concentrations of anthocyanins, a complex of natural plant colors similar in form to flavones, that act as natural oxygen radical scavengers. Key among dark colored species of grapes is malvidin, a nonoxidizable anthocyanidin, which is red under acidic conditions and shifts to purple at neutral pH. Rapid-rise breads made with 1–4% Syrah grape skin flour have deep purple interiors (Fig. 3).

In addition to their novelty, red grape skin flours provide health benefits. Anthocyanins have recently been found to support brain and eye health (8). Other flavonoids, such as catechin and epicatechin and their gallic acid esters (EGC and EGCG), are found in high concentration in grape skins. Although green tea and cocoa are often referenced when talking about antioxidant levels in foods, a study performed at The National Food Lab showed that grape seed and skin flours contain more than five times the catechin and epicatechin found in cocoa and green tea (13).

Flavor Compounds. Grape seed and skin flours impart varietal wine flavors and tannins to dough and batter mixtures. The tannin content interacts with the perception of sugar and adds textural depth as well. For example, brownies made with Zinfandel grape skin flour have a wine-like character and less cloying texture. Gluten-free cookies made with combinations of grape seed and skin flours were more acceptable in consumer tastings because the typical starchy taste was decreased by the addition of tannin and other polyphenols that brought the formula back into balance. Glutamic acid makes up 21–26% of the total protein in grape seed (5,14) and could be responsible for adding savory, longer lasting flavors to artisan breads.

Fig. 1. Gas cell formation in sourdough wheat bread containing 3% California Chardonnay grape seed flour (in-house Chardonnay cultivated starter).

Fig. 2. Influence of 1 and 2% California Chardonnay grape seed flour addition on gas cell formation in rapid-rise wheat bread (1% [wt/wt] yeast added).

Consumer Acceptance. Consumer acceptance of grape seed and skin flours was evaluated in a study at Washington State University, Pullman. The study showed that the majority of consumers did not understand the concept of grape flours but approved of the texture and flavor complexities they added to common foods (11). The study group found the color unacceptable when grape seed and skin flours were incorporated into noodles. However, the variety used (Cabernet versus Merlot), amount of flour incorporated, and color intensity were influential factors in acceptance. The participants believed that the foods containing grape seed and skin flours were intrinsically healthier, had good flavor (depending on the food matrix), and had a sustainability message that they appreciated.

Effects of Variety and Location. A literature review of grape phenolics in relation to cultural practices and environment demonstrated that differences in location, grape variety, and weather all have significant effects on the concentration and types of phytonutrients in grapes (4). The source of the grape, as is the case for most plant-based ingredients, matters. In the western United States, higher night time temperatures adversely affect the amounts and types of polyphenols in grapes, so grapes grown in hotter climates have different profiles than those grown on the coast. Coastal grapes benefit from cool nights, warm sunny days, and protective marine influences. Hotter inland regions generally do not cool down below 90°F (32°C) at night during key ripening stages, and grapes cannot produce some of the polyphenols they might otherwise produce (7). Water and sunlight can also dramatically impact the concentrations and balance of these compounds.

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Fig. 3. Influence on color of rapid-rise wheat dough (1% [wt/wt] yeast added) containing California Syrah grape skin flour. Left to right: control, 1, 2, and 4% addition.

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