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The Market Potential of Grape Waste Alternatives

Kyle Dwyer[1], Farah Hosseinian[1,2] & Michel Rod[3]

[1] Department of Chemistry, Carleton University, Ottawa, Ontario, Canada

[2] Institute of Biochemistry, Carleton University, Ottawa, Ontario, Canada

[3] Sprott School of Business, Carleton University, Ottawa, Ontario, Canada

Correspondence: Farah Hosseinian, Department of Chemistry, Carleton University, Ottawa, Ontario, Canada. E-mail: Farah.Hosseinian@carleton.ca

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Abstract

During wine production, approximately 25% of the grape weight results in by-product/waste (termed 'pomace' which is comprised of skins and seeds). Currently, most pomace is being composted to be reintroduced into the vineyards to complete the carbon cycle. Due to the increasing consumer demand for the use of natural over synthetic compounds, and because of increased attention to sustainability of agricultural practices (Fontana, Antoniolli, & Bottini, 2013), there is a vast array of applications for grape pomacebioactives including: functional foods (dietary fiber + polyphenols), food processing (biosurfactants), cosmetics (grapeseed oil + antioxidants), pharmaceutical/biomedical (pullulan) and supplements (grape pomace powder). To date, there has been no assessment as to the market potential for value-added usage of grape pomace. This paper seeks to address this gap. The annual production of grape pomace along with its multitude of applications, create an opportunity to discover an unexploited market with great commercial potential.

Keywords: vinification, grape, waste, compost, market potential, antioxidant

1. Introduction and Background

1.1 Canadian Vinification

In 2007, the worldwide production of wine surpassed 27 billion liters; however from 2007 to 2011, there was a decline in worldwide production due to unfavourable weather conditions.Canadian winemaking contributes approximately 0.2% to the total worldwide production of wine (Wine Institute, 2012). This percentage may seem insignificant, but the comparison in Table 1 presents the stability of Canadian vinification.

Table 1. The Canadian and worldwide vinification statistics from 2007 to 2010

Acreage (acres)						
	2007	2008	2009	2010	% of Total	Change*
Worldwide	18,594,500	18,567,600	18,467,600	18,174,700	100%	-2.3%
Canada	23,700	23,400	27,300	27,300	0.2%; 50th	+15.2%;
Rank						9th
Wine Production (Liters '000)						
	2007	2008	2009	2010	% of Total	Change*
Worldwide	27,226,321	25,920,669	26,389,840	26,384,872	100%	-3.09%
Canada	50,000	50,000	52,000	56,000	0.2%; 31st	+12.0%;
Rank						5th

Source: Wine Institute 2012.

*('10 / '07).

The 0.2% of total acreage and liters produced rank Canada 50th and 31st worldwide, respectively. The impact of Canadian viticulture throughout the world may seem insignificant, but its growth and development are substantial. The increase in total acreage for Canada from 2007 to 2010 is ranked 9th out of the top 50, with an increase of 15.2%. This is compared to the worldwide change from 2007 to 2010 showing a decrease of 2.3% total acreage.

With an overall 3.09% worldwide decrease in liters produced from 2007 to 2010, Canada is ranked 5th out of the top 31st countries with an increase of 12.0% of liters produced throughout the same period. The major grape crops for Canadian wine are produced in Ontario and British Columbia (B.C.). Tables 2 and 3 provide the total viticulture from Ontario and B.C., respectively. Ontario comprises approximately 75% of total grape production towards wine-making. In both provinces, a decrease in grape production was observed in 2009/2010; unfavourable climate conditions were the most probable factors (279 mm of rainfall in 2007 compared to 542 mm and 561 mm in 2008 and 2009, respectively; Grape Growers of Ontario, 2012). This decline reversed with a record high production of grapes for both provinces in 2011.

Table 2. The annual grape production and uses in Ontario from 2007 to 2011

	2007	2008	2009	2010	2011
Total Production(t)	56,315	60,780	47,595	53,747	64,495
Wine (t)	46,290.93	51,723.78	43,359.045	45,577.456	53,724.335
Juice & Jam (t)	3,773.105	2,613.54	2,617.725	2,418.615	1,999.345

Source: Grape Growers of Ontario Annual Report 2012.

(t) = tonnes.

Table 3. The annual grape production for wine in British Columbia from 2006 to 2011

	2006	2007	2008	2009	2010	2011
Total Production (t)	20,369	19,777	22,275	19,879	17,778	22,722

Source: www.winebc.org

(t) = tonnes.

With the increasing success of Canadian viniculture, the annual addition of wineries in both Ontario and B.C. provides stability to the market outlook of wine for the future. The increase in vineyard acreage from 2004 to 2011 is listed in Table 4.

Table 4. Total vineyard acreage in Ontario and British Columbia (B.C.)

	2004	2006	2007	2008	2009	2010	2011
Ontario	-	-	16,460	16,350	17,740	15,902	15,993
B.C.	5,462	6,632	-	9,100	-	-	9,866

Sources: Ontario Ministry of Agriculture and Food (OMAFRA); www.winebc.org

2005 omitted in both sources.

1.2 Grape Pomace From Wine Making

After the grapes are harvested, they are processed into wine. Initially, the stem (or stalk) is removed due to the large amount of tannins contained within (Grainger & Tattersall, 2005). Stems may be added to the fermentation process depending on the specific wine composition desired. The grapes are then crushed as they travel through rollers calibrated at a specific pressure. Crushing expels the juice from within the grape, containing the necessary sugars, glucose and fructose, for fermentation (Grainger & Tattersall, 2005).

To prepare red wine, the extracted juice along with the remaining pulp, skin and seeds (pomace) are fermented together. The addition of pomace, more specifically the skin, provides the pigments (anthocyanins) necessary to create the red colour of wine. Once fermentation is near complete, the must (juice and pomace together) is pressed to extract any remaining juice from within. After fermentation the juice is removed with only the pomace remaining (Grainger & Tattersall, 2005). To create white wine, the stems are removed and the grapes are pressed before fermentation compared to red wine processing, where pressing occurs after fermentation. Since colour is undesirable in white wine, the pomace is not included in the fermentation process (Grainger & Tattersall, 2005). In Ontario and B.C the percentages of produced red wine were: 39% and 52%, while for white wines were 61% and 48%, respectively.

This is a very spartan description of the beginning of the wine making process, but for the purposes of this paper, the underlying significant factor is the production of grape pomace from both wine types (Jin & Kelly, 2009). The amount of pomace produced from wine-making is dependent upon the species of grape (cultivar) as well as the pressing process/equipment used. Many studies have determined pomace to be approximately 20%-30% of the original grape weight (Llobera & Canellas, 2007; Chand et al., 2009; Prozil, Evtuguin, & Lopes, 2012; Yu & Ahmedna, 2013). This is consistent with the values obtained through personal communications with key informants from the Noble Ridge vineyard in B.C., where pomace totaled 29.77% (personal communication, 2013). Therefore, based on the total amount of grape production in Ontario and B.C. (Grape growers of Ontario; Wines of British Columbia), the amount of pomace produced is illustrated in Table 5 where total grape production is multiplied by 25% as the midway point in the estimated range (20%-30%) of the proportion of grape weight comprised of pomace.

Table 5. Pomace production in Ontario and B.C. from 2007 to 2011

	2007	2008	2009	2010	2011
Ontario grapes produced (t)[1]	56,315	60,780	47,595	53,747	64,495
B.C. grapes produced (t)	19,777	22,275	19,879	17,778	22,722
Total grapes produced (t)	76,092	83,055	67,474	71,525	87,217
Pomace produced (t)	19,023.02	20,763.75	16,868.5	17,881.25	21,804.25

[1](t) = tonnes.

[2](Total grapes produced) × 0.25.

1.3 Grape Pomace as a Waste Alternative

With increasing consumer demand for the use of less synthetic compounds and more natural/organic compounds, the utilization of waste/by-products (natural compounds) for alternative uses has been a focus of research (Cheng, Bekhit, Sedcole, & Hamid, 2010; Rockenbach et al., 2011). An example of major by-product development is the use of whey proteins as bioactive peptides. Originally, during the manufacturing of cheese products, whey was considered a waste product. As research determined the beneficial advantages of whey, the once ignored by-product then came to be considered a functional food which is now produced and marketed as a supplement (Marshall, 2004).

The views about the beneficial effects of wine (and indirectly grape pomace) were introduced in the 1990s due to the theorized “French paradox” (Renaud & Lorgeril, 1990). It was believed that the high consumption of red wine in France reduced the prevalence of coronary heart disease (CHD) even though diets contained large amounts of saturated fats (Renaud & Lorgeril, 1990). Later studies believed this “paradox” to be due to the phenolic compound, resveratrol found in red wine. Phenolic compounds have been proven to inhibit LDL (low-density lipoproteins) oxidation and reduce the risk of CHD (Pokorny, Yanishlieva, & Gordon, 2001).

Although inhibition of LDL oxidation by resveratrol may not be the exact mechanism underlying the “French paradox”, the determination of phenolic compounds within wine created an awareness of their beneficial properties leading to a significant amount of wine-phenolic research (Schieber, Stintzing, & Carle, 2001). In addition to their health properties, from a commercial perspective, it has been argued that the economic value of these compounds exceeds US$30 billion based on 2008 grape wine production data (Rayne, Karacabey, & Mazza, 2008).

During wine making, the grapes are crushed and pressed, which does not alter their chemical composition. Fermentation, in red wine processing, is the only significant process that occurs before the pomace/waste is produced, but overall does not induce large chemical changes. Therefore, in both red and white grape pomace, a significant amount of bioactive compounds are retained (Arvanitoyannis, Ladas, & Mavromatis, 2006a). It has been determined that approximately 70% of the phenolics remain within the grape pomace after processing (Ratnasooriya & Rupasinghe, 2012).

Over the decades, the utilization of grapepomace for alternative uses has been inefficient, with large portions discarded in landfills. Large amounts of pomace are produced during a short period of harvesting (August to October), which increases the concentration of pomace per area of landfill. This may be detrimental to the environment, due to the phenolic compounds decreasing the pH of the pomace as well as increasing resistance to biological degradation (Bustamante et al., 2008). Other environmental problems include: surface and ground water pollution; foul odors; attraction of flies and pests which may spread diseases; and leachates of tannins and other compounds with the possibility of oxygen depletion in the soil and ground waters, affecting surrounding flora and fauna (Arvanitoyannis, Ladas, & Mavromatis, 2006b; Chand et al., 2009).

Therefore, the purpose of this paper is to determine the market potential of grape waste (pomace) and the alternative uses of its bioactives.

2. Literature Review

2.1 The Composition of Grape Pomace

To be able to determine the alternatives uses of grape pomace bioactives, quantification studies of the bioactives must be performed. It is known that grape pomace consists of the unused skins, seeds and stems (if not removed prior to crushing and pressing) during vinification. The following studies illustrate the sugar content, dietary fiber content and total phenolic content of grape pomace skins and seeds.

Jiang et al. (2010) conducted research to analyze the composition of various red and white pomaces using grape varieties from the U.S. Table 6 illustrates the basic chemical composition of grape pomace from five different *Vitis vinifera* cultivars: two white, Morio Muscat and Muller Thurgau; and three red, Cabernet Sauvignon, Pinot Noir and Merlot. The chemical composition seen in Table 6is noticeably different for each grape variety. The largest variation is the total soluble solid content (TSSC) between red and white grapes. TSSC is a measure of the soluble sugar content. The average TSSC for white and red is 78.15% and 26.03%, respectively. This is understandable since red pomace is fermented (sugar is used as a substrate) with the extracted juice, therefore reducing the TSSC. The average percentages for all five types are 82.12%, 13.77% and 1.36% for skin, seeds and stem, respectively.

Table 6. Basic chemical composition of five fresh (wet) *V. vinifera* grape pomaces; Adapted from Jiang et al. (2010)

Grape Variety	Skin (%)	Seed (%)	Stem (%)	TSSC* (%)
Morio Muscat	85.99	12.77	1.25	83.9
Muller Thurgau	90.67	7.84	1.49	72.4
Cab. Sauvignon	77.41	20.91	1.68	28.2
Pinot Noir	73.35	12.34	0.54	27.7
Merlot	83.18	14.98	1.84	22.2

*Total soluble solid content.

Deng et al. (2011) conducted a study using the same grape cultivars as in Table 6. This study focused on the chemical composition of the grape pomace skins. The grape skins were manually separated from the stems and seeds; then ground in a disintegrator; dried in an environmental chamber; and finally milled. Contrary to the values in Table 6, the values in Table 7 are based on the percentage of dry matter (moisture removed) of grape pomace. The white grape pomaces: Muller Thurgau and MorioMuscat, contained significantly higher amounts of soluble sugar, consistent with Table 6. This study corroborated the presence of a significant amount of dietary fiber within grape pomace skins. The red pomace samples contained between 51% to 56% total dietary fiber, whereas the white grape pomace contained approximately half of the percentage of red total dietary fiber (17%-28%).

Although there were significant differences between the red and white pomaces, both had insoluble dietary fiber percentages above 97% (insoluble dietary fiber / total dietary fiber). Bound condensed tannins were also analyzed for all types of grape pomaces. The average percent of tannins were 17.43% and 7.29% for red grape pomace and white grape pomace, respectively.

Table 7. White and red grape pomace skin compositions; Adapted from Deng et al. (2011)

Composition (% DM)	Muller Thurgau (W)	Morio Muscat (W)	Cabernet Sauvignon (R)	Merlot (R)	Pinot Noir (R)
Soluble sugar	55.77	77.53	1.71	1.34	1.38
Total dietary fiber	28.01	17.28	53.21	51.09	56.31
Insoluble dietary fiber	27.29	16.44	52.40	49.59	54.59
Soluble dietary fiber	0.72	0.84	0.81	1.51	1.72
Condensed tannins	8.53	6.04	16.14	16.26	19.89

DM = dry matter; (W) = white wine pomace; (R) = red wine pomace.

In the same study by Deng et al. (2011), red and white grape skin phenolics were analyzed. Phenolics in wine can be classified as flavonoids or non-flavonoids. Flavonoids consist of anthocyanins, condensed tannins (proanthocyanidins) and flavan-3-ols. Non-flavonoids consist of phenolic acids and stilbenoids (i.e., resveratrol). The total phenolic and flavonoid content of both white (Muller Thurgau and Morio Muscat) and red (Cab. Sauvignon, Merlot and Pinot Noir) pomace skins from the U.S as well as the 2 extraction methods performed: A) 0.1% HCl / 70% acetone / 29.9% water using an ultrasonic unit; B) 70% acetone / 30% water using an environmental shaker, areshown in Table 8.

Based on both extraction methods, A) was the most efficient with higher yields in every category. Therefore, adding hydrochloric acid (HCl) increases phenolic extraction. Overall, the red grape pomace skins contained a higher amount of total phenolics, expressed as gallic acid equivalents (Folin-Ciocalteau assay). Anthocyanins were not found or were below the detectable limit in white pomace skins. There was no clear distinction between total flavanol and total proanthocyanidins and red or white pomace.

Table 8. Red and white grape pomace skin phenolics; Adapted from Deng et al. (2011)

Wine Grape Pomace Skins	Total Phenolic Content (mg GAE/g DM*)		Monomeric Anthocyanins (mg Mal-3-glu/g DM)		Total Flavanol Content (mg CE/g DM)		Extractable Proanthocyanidins Content (mg/g DM)	
	Method of Extraction							
	A	B	A	B	A	B	A	B
Muller Thurgau	15.8	11.4	-	-	58.9	40.3	19.4	10.5
Morio Muscat	11.6	11.4	-	-	31.0	25.0	8.0	7.7
Cabernet Sauvignon	26.7	12.7	0.89	0.85	54.3	42.0	17.2	7.7
Merlot	25.0	18.3	1.42	1.09	61.2	37.0	24.1	15.8
Pinot Noir	21.4	11.2	0.29	0.26	42.6	32.5	11.9	8.0

DM = dry matter.

Although B.C. produces a higher percentage of red wine, Ontario produces more wine in total. Based on the tonnes of pomace / the percent of red wine produced in Ontario and B.C., in 2011, Ontario produced 6,288 tonnes of red pomace whereas B.C. produces approximately half that amount with 2,954 tonnes of red pomace.

It is generally accepted that more than 3/4 of grape pomace consists of the grape skin for the five grape cultivars analyzed. Both red and white pomace contains similar percentages of skin (73%-90%). Red skin contains higher amounts of phenolic compounds and dietary fiber but contains lower total sugar. White pomace on the other hand, contains higher sugar content with a lower phenolic and dietary fiber content. Both pomace types complement each other with their respective bioactive elements.

The previous two studies determined sugar, phenolic and dietary fiber content of red and white pomace skins but another important component of grape pomace is the bioactive compounds extracted from grape seeds. Jiang et al (2010) calculated seeds to constitute 7-20% of the grape pomace. Other studies have found varying results, ranging from 20-26% (Baydar & Akkurt, 2001) and as high as 38-52% (Maier, Schiber, Kammerer, & Carle, 2009). This wide range is most likely attributable to the differences found across grape cultivars.Grape seeds are known to be a valuable source of oil. Baydar and Akkurt (2001) analyzed the oil contents of the red and white pomace seeds. Table 9 displays the results from the study.

Table 9. Seed oil contents; Adapted from Baydar and Akkurt (2001)

Grape seed cultivars	Oil Content (% v/w)*	Degree of unsaturation (%)	Tocopherol (mg/kg)
Red	13.1 – 19.6	86.6 – 89.3	357 – 578
White	14.7 – 17.8	86.5 – 88.1	364 – 486

*Avg. (red & white) = 16.3%.

They found the oil content for both red and white pomaceis similar with a total average of 16.3% (v/w). Of the 16.3% oil content, approximately 87% is unsaturated which is known to be more beneficial to health as compared to saturated oils. Tocopherol or vitamin E, an antioxidant, was analyzed and was found to be in higher concentrations in red seeds compared to white seeds. Due to the high percentage of unsaturated oil found within the grape seeds, Da Porto, Porretto and Decorti (2013) further analyzed their composition.

Table 10. Grape seed oil composition; Adapted from Da Porto et al. (2013)

Fatty Acid %	100% yield	90% yield
Linoleic acid	72.35	71.58
[Oleic] acid	16.79	17.91
Palmitic acid	7.22	6.83
Stearic acid	3.07	3.04
[Linolenic] acid	0.39	0.44
Palmitoleic acid	0.16	0.19

[ ] = alternative name.

The seeds were not distinguished as being from red or white pomace, but due to the significant similarities between both types, distinction is not necessary. Extraction of fatty acids was performed by two methods: soxhlet and ultra-sound. Both methods had similar values. Linoleic acid (omega-6 fatty acid) represented approximately 72% of the grape seed oil analyzed.

Previous studies have determined grape pomace skins, more specifically red skins, to be a significant source for phenolic compounds. Grape seed studies have uncovered the presence of phenolic compounds and Table 11 summarizes the findings of Maier et al. (2009). They determined that grape seeds contain higher concentrations of phenolic acids relative to flavanoids. This finding was also observed within the seed residues (oils). This adds to the beneficial effects of grape seeds: high in omega-6 fatty acids as well as containing phenolic acids and smaller amounts of flavanoids.

Table 11. Grape seed phenolics for red and wine cultivars; Adapted from Maier et al. (2009)

	Total Phenolic acid (mg/kg DM)		Total Flavanoid (g/kg DM)	
Grape cultivars	Seeds	Residue/Oil	Seeds	Residue/Oil
Cabernet Mitos (Red)	419.3	262.8	4.39	2.52
Lemberger (Red)	498.2	275.2	5.91	4.48
Spätburgunder (Red)	280.0	263.2	18.78	13.50
Samtrot (Red)	1165.8	492.7	14.76	9.69
Müller-Thurgau (White)	188.7	147.4	7.49	5.65
Kerner (White)	264.2	164.0	5.34	3.71

DM = dry matter.

There is a large variation between grape seed cultivars, but red grape seeds contain higher amounts of phenolic compounds compared to the white grape seeds. This is observed for both seeds and seed oils. Grape seeds not only contain oils and phenolic compounds, but are comprised of approximately 40% fiber (Kim et al., 2006). Grape pomace, consisting of skins, seeds and stems (although not mentioned due to a lack of research) is a significant source of dietary fiber, phenolic compounds and soluble sugars. Red grape pomace contains a higher quantity of phenolics while white grape pomace contains a higher quantity of sugars.

Most of the studies cited were conducted within the past decade. Extraction techniques are still being evaluated to determine the most efficient method (highest yield) with the least synthetic compounds utilized based on consumer demands.

The majority of grape pomace studies have been conducted outside of Canada. Since Canada represents only 0.2% of the world-wide wine production, grape pomaceresearch has not been a significant priority for Canadian researchers. Therefore, most of the literature cited in this review are based on grape compositions from the United States and overseas, i.e., Spain. This is significant due to varying soil characteristics within each country. Soil composition is one of the most important factors in viniculture creating variations in nutrient and water demands (Grainger & Tattersall, 2005). Climate differences within countries may also contribute to the variations found within grape cultivars (Deng et al., 2011).

3. Research Methodology

3.1 Market Potential – Bioflavia and PC Oil

Grape pomace contains polyphenols (flavanoids and anthocyanins), dietary fiber and oils, each with characteristic bioactive properties. Identifying said properties will determine alternative applications of grape pomace creating profitability and market potential. A current application of grape pomace is its use as a supplement. The organic grape pomace product, Bioflavia, is currently sold for approximately $30 (Canadian). Bioflavia consists of dried and ground, red grape skin powder; sold in bottles containing 300 g. The Bioflavia powder can be added to smoothies or alternative beverages.It can also be added during cooking i.e.,as a substitute for yeast in bread-making.

The purpose of this paper is toattempt to determine the market potential of grape pomace alternatives. Since these alternative uses are in the early stages of development, the market potential for grape pomace is determined using Bioflavia, the supplement as a suitable reference.

Bioflavia consists of only red grape skin pomace. Due to the different percentages of red wine produced in Ontario and B.C., the amount of red pomace skin produced in both provinces from 2007 to 2011 was determined separately. The values from 2011 will be discussed as an example for the remaining years (2007-2010), which are displayed in Table 12.

Table 12. Market potential of Ontario red pomace skins using Bioflavia as a reference

	2007	2008	2009	2010	2011
Grapes produced (t)	56315	60780	47595	53747	64495
Pomace produced(t)	14078.75	15195	11898.75	13436.75	16123.75
Red wine pomace (t)	5490.71	5926.05	4640.51	5240.33	6288.26
Red pomace skin (t)	4281.66	4621.13	3618.67	4086.41	4903.59
Market Potential ($)	435,949,814.3	470,514,600.2	368,445,909.8	416,070,224.1	499,273,431.1

In 2011, 64,495 tonnes of grapes were produced. An initial assumption based on the literature, is that grape pomace is approximately 25% (w/w) of the grapes produced, equaling 16,124 tonnes of pomace. Bioflavia only uses red grape pomace therefore the total amount of red pomace was determined by multiplying 16,124 tonnes of pomace by 39% (amount of red wine produced in Ontario). This is equivalent to 6,288 tonnesof red grape pomace. The skins are the only portion of the red grape pomace utilized therefore the 6,288 tonnes were multiplied by 77.98% (average red skin percentage of grape pomace) equaling 4,903 tonnes of red grape skin. To determine the market potential, the number of Bioflavia containers that 4,903 tonnes of red grape skin could potentially yield was determined and then multiplied by the price of $30. The market potential for 2011 was $499,273,431.10.

The same process was performed for red grape skins in B.C. The results are displayed in Table 13.

Table 13. Market potential of British Columbia red pomace skins

	2007	2008	2009	2010	2011
Grapes produced (t)	19777	22275	19879	17778	22722
Pomace produced (t)	4944.25	5568.75	4969.75	4444.5	5680.5
Red wine pomace (t)	2571.01	2895.75	2584.27	2311.14	2215.395
Red pomace skin (t)	2111.313412	2377.9899	2122.202524	1897.908168	1819.282374
Market Potential ($)	214,969,709.0	242,122,175.6	216,078,416.6	193,241,213.8	185,235,692.8

To clarify, this market potential is based on the assumption that every gram of red pomace skin is sold (100%). Realistically, the market potential will be lower, since a certain proportion of pomace is returned to the vineyards as compost but this value provides an understanding of the significant amount of pomace that is produced in Ontario and B.C. Future research is required to evaluate the actual market (demographics) of Bioflavia or alternative powders to be able to determine the true market potential.

The values from Table 12 and Table 13 were only based on red pomace skins therefore they do not include any white skins and red or white pomace seeds. The application of white skins or seeds would increase the market potential. This is observed when determining the market potential for grape seed oil. Just as Bioflavia was used as a reference price to determine red grape skin potential, President's Choice (PC) grape seed oil (750 mL; $6.99) was used to determine the pomace seed oil market potential, Table 14.

The market potential for grape seed oil was calculated using a similar method to that for the red skin pomacecalculation of market potential; however instead of separating both provinces, grape production for Ontario and B.C. was combined. The total pomace produced (2011) was multiplied by 13.768% (average seed composition of pomace) giving 3,002 tonnes of pomace seeds.

Table 14. Market potential of Ontario and B.C. grape seed oil

	2007	2008	2009	2010	2011
Grapes produced (t)	76092	83055	67474	71525	87217
Pomace produced (t)	19023	20763.75	16868.5	17881.25	21804.25
Pomace seeds (t)	2619.08664	2858.7531	2322.45508	2461.8905	3002.00914
Pomace seed oil (mL)	472488862.4	515725207.2	418975891.1	444130340.7	541568904.9
Market Potential ($)	4,403,596.198	4,806,558.931	3,904,855.305	4,139,294.775	5,047,422.194

To be able to determine the pomace seed oil quantity, pomace seeds (3,002 t) were multiplied by 16.3% (average oil content of seeds) equaling 489.3 tonnes of seed oil. Seed oil (489.3 t) was then converted to grams. The density of grape seed oil (0.92 g/mL) were used to convert the grams of grape seed oil to mL (Grape seed oil MSDS). The market potential was determined based on the 750 mL bottle at a price of $6.99, equalling $5,047,422.20.

The market potential values were calculated based on an assumption of 100% of the extracted grape seed oil being available for sale. Similar to the red grape skin market potential, these values will decrease when the true market (how many bottles are sold) is determined. It is also important to recognize that the seed % of pomace may be higher in other grape cultivars, which would lower the skin % of pomace (currently 77.89%) and therefore decrease the market potential. More research is needed to determine the pomace composition of Canadian grape cultivars to determine the actual pomace percentage of skin and seeds.

The market potential for red grape skin as well as grape seed oil, provide values that put the large amount of grape pomace produced annually, into perspective. The market potential was determined using red grape skin and grape seed oil because these products are currently being sold. The true market potential will no doubt decrease due to costs of transportation, extraction and processing, but overall, for the current known uses of grape pomace, the market potential is substantial given the volume of grape pomace produced annually.

3.2 Market Potential and Grape Pomace Composting

As previously noted, the market potential determinations for both red grape skins and grape seed oil were based on 100% utilization. These market potentials decrease when a large portion of the produced grape pomace is used to create compost which is then recycled back into the vineyard (Bertran, Sort, Soliva, & Trillas, 2004).

Composting is based on aerobic microbial decomposition. Organic compounds are broken down (decomposed) into natural elements such as carbon and nitrogen. This is a very simplified version of the composting process as a multitude of factors are involved in composting biology and chemistry. For optimal composting, the material being composted must have a high moisture content and contain a sufficient carbon-to-nitrogen (C:N) ratio. The high C:N provides nutrients for the microbes to survive and continue degradation (Bertran et al., 2004). A study in 2001 provided the chemical characterization of fresh grape pomace, which is displayed in Table 15. The chemical composition after composting is also displayed in Table 15, providing a before and after comparison of grape pomace composting.

Table 15. Chemical characterization of fresh grape pomace (Ferrer, 2001)

Chemical Property	Before Composting	After Composting3
Moisture (wt%)1	73.56	-
Carbon (wt%)2	46.60	32.18
Nitrogen (wt%)2	1.73	2.353
C:N ratio	26.94	13.67

[1]Wet weight basis; [2]Dry weight basis; [3]Mean value (n=3).

The optimal initial C:N of a compost is between 25:1 and 35:1. As shown in Table 16, the C:N of grape pomace is approximately 27:1, therefore it qualifies as an optimal substrate for composting. After composting, the nitrogen content increased to 2.35 (wt%). This is beneficial as nitrogen content in soil is influential in determining vineyard growth (Bell & Henschke, 2005).

The theoretical average amount of nitrogen needed for a vineyard is 55 kg N/ha (Spayd, Nagel, & Edwards, 1995; Wiens & Reynolds, 2008; OMAFRA, 2009). This is equivalent to 22.267 kg N/acre (1 ha = 2.47 acres). As stated, the market potential of grape pomace as a suitable supplement decreases as increased pomace is utilized as compost. Although composting grape pomace increases the nitrogen content, using composted grape pomace alone to supply vineyards with nitrogen is neither feasible nor economical. To validate 1) due to the significant amount of composted grape pomace needed to supply 22.267 kg N/acre and 2) the other nutrients needed for vineyard growth, i.e., phosphorus, potassium and magnesium, are not adequately supplied by grape pomace compost.

To validate 1) the theoretical amount of grape pomace needed to adequately supply 22.267 kg N/acre was determined. In 2011, Ontario and B.C. harvested 25,859 acres of grapes. Based on this acreage and 2.35% weight (nitrogen), the amount of pomace needed to provide 22.267 kgN/acre is 24,065 tonnes. In 2011, only 21,804 tonnes of pomace were produced. Therefore, fertilizer (ammonium nitrate; 34% nitrogen) must be applied to soils along with grape pomace compost to ensure all nutrient demands are satisfied. Table 16 provides the 2011 theoretical values for the grape pomace compost / fertilizer ratios added to Ontario vineyards and their effect on market potential (using retail Bioflavia values). British Columbia costs for ammonium nitrate were not located, therefore only Ontario is included in Table 16.

Table 16. Theoretical values for grape compost/fertilizer ratios and effect on market potential (2011 values)

Compost	100%	75%	50%	25%	0%
Fertilizer	0%	25%	50%	75%	100%
Compost Used (Kg N)	356,116	267,087	178,058	89,029	0
Fertilizer[1] Used (Kg N)	0	89,029	178,058	267,087	356,116
Unused Pomace(t)	917.0	4,718.86	8,520.57	12,322.5	16,124.0
Cost of Fertilizer[2] /acre ($)	0	8.8	17.6	26.4	35.2
Market Potential[3] ($)	28,362,269.3	153,877,800.6	277,848,160.7	401,825,694.8	525,789,207.0
Market Potential /acre ($)	1,773.4	9,621.6	17,373.11	25,125.098	32,876.2

[1]Ammonium nitrate (34% nitrogen); [2]$547.43/tonne (O.F.I.M.P).

It was previously noted that there was not enough pomace produced to adequately supply the nitrogen requirements for vineyards. As shown in Table 16, if 100% of the compost is used, there would remain 917 tonnes of pomace. This is contradictory to the previous statement due to Table 16 only assessing Ontario's values and not both provinces combined. Ontario harvests more grapes per acre compared to B.C. (Statistics Canada), therefore with 100% compost use, Ontario has remaining pomace whereas B.C. does not. Based on Bioflavia's pomace retail price, the remaining 917 tonnes of grape pomace would have a market potential of 28.3 million dollars.

According to a small sample of Ontario (4) and B.C. (1) wineries, virtually 100% of the pomace produced is composted on-site to be recycled into the vineyard. One winery stated their belief that most of the smaller wineries compost their grape pomace on-site to reduce costs and that the larger wineries send their pomace to the landfill or to be converted into biogas.

If vineyards/wineries composted only 50% of their pomace each year, the theoretical market potential would be greater than 250 million dollars. Again, this is if 100% of the grape pomace was sold. This profit would undoubtedly cover the costs of using 50% fertilizer.

More research is required to determine the environmental impact of composting grape pomace on-site. Another area of debate is the amount of nutrients yielded from composting 100% of the produced grape pomace. Studies have shown that the nitrogen contained within the grape pomace compost is considered “slow-releasing” and if not properly distributed year-to-year, there may be an abundance of nitrogen which can be detrimental to grape vine growth (E.A.S.I.B.C, 2000; OMAFRA, 2012).

A 2001 study looked at the optimal amount of grape waste required for use as a soil conditioner for corn seed germination. Corn seed germination is a different context than vineyard growth, but it was determined that a dose of 3000 kg/ha equivalent to 1215 kg/acre, was optimal for soil conditioning. Triple superphosphate was also needed to ensure all nutrient demands were achieved (Ferrer et al., 2001). This study although tested on corn seed germination, showed the immense amount of grape pomace compost required for application as a soil conditioner (fertilizer was still needed).

Another study, performed at Brock University in the Cool Climate Oenology and Viticulture Institute (CCOVI) tested the efficacy of foliar-applied (leaf) organic fertilizers on Niagara-on-the-lake, Baco Noir grapevines. A control treatment using ammonium nitrate was performed (51 kg N/ha). Results showed that the foliar application of the organic fertilizers used less than 10% of the nitrogen in the control and surpassed the control in almost all yield, fruit composition and vine nutrition variables (Wiens & Reynolds, 2008). The increased cost of the foliar treatment was offset by the increase in yield. This study was able to reduce the amount of nitrogen required to obtain efficient yields and compositions. This is notable since less grape pomace compost would be required for application. Both studies in combination are examples of how future research might proceed in the domain of vineyard composting.

3.3 Alternative Bioactive Applications

Grape pomace composting is beneficial, to a certain degree. Currently, most of the grape pomace produced is composted. The amount of pomace being composted may be reduced in the future as more profitable applications of grape pomace bioactives are determined.

The composition of grape pomace was illustrated earlier and was shown to contain an appreciable amount of dietary fiber, phenolic compounds, oils and sugars. Two retail products have been discussed; Bioflaviagrape skin pomace and PC grape seed oil, both of which are currently sold in the market. The increased awareness of the bioactives contained within grape pomace has led to associated research and development in many industries.

The food industry has proposed many theoretical applications for the use of grape pomacebioactives. A study by Rivera et al. (2007) found grape pomace to be a possible input to biosurfactant production. The glucose in grape pomace can be used as a substrate for lactic acid production, through homolactic fermentation. Biosurfactants are important for food processing applications due to their emulsifying abilities. Increased consumer demand for natural additives over synthetic additives, has increased the importance of natural biosurfactants. Biosurfactants produced from grape pomace or any natural products have lower toxicities and are more biodegradable than synthetic biosurfactants (Rivera et al., 2007). The cost of production of biosurfactants is competitive therefore utilization of grape pomace may pose a cheaper substrate for production. Rivera obtained a biosurfactant concentration of 4.8 mg/L and a yield of 0.60 mg per gram of sugar.

In bakery and ice cream products, biosurfactants control consistency, prolong staling and solubilising of flavour oils, as well as improving dough stability, texture and volume (Nitsche & Costa, 2007). Biosurfactants can be added to any food product containing aqueous solutions as well as lipid solutions, i.e., salad dressing.

Another application from grape pomace is the production of pullulan. Pullulan is a non-ionic exopolysaccharide produced from the yeast-like fungus Aureobasidium (Rekhaand & Chandra, 2007). Pullulan is biodegradable, impermeable to oxygen, non-hygroscopic and non-reducing, easily soluble in hot and cold water and has high film-forming capabilities (Rekhaand & Chandra, 2007). Pullulan can be added to food to increase texture and provide low-calorie bulk. Other applications of pullulan include: health care (lotions and shampoos) and pharmaceutical (denture adhesives and capsules for supplements) (Farris et al., 2012). A future application currently being developed is a pullulan-based antimicrobial active packaging system (Farris et al., 2012).

Another area of grape pomace bioactive application is food preservation. The biofilms previously discussed were externally added to foods, but other bioactives such as antioxidants can be added internally to preserve food (Sánchez-Alonso et al., 2007; 2008). Especially with respect to meat and meat products, the use of natural antioxidants such as the phenolics contained in grape pomace, are greatly preferred over synthetic antioxidants (Ahmad et al., 2013)

The antioxidants and oils extracted from grape pomace can also be used in the cosmetic industry. Burke (2004) showed that the topical application of antioxidants helps protect skin and reverses any UV-induced free radicals. Vitamin E has also been found to be effective as a topical application. This is significant due to the amount of vitamin E that can be extracted from grape seeds. It has also been determined that oil rich in fatty acids (i.e., grape seed) are beneficial to the skin. Linoleic acid, the most abundant fatty acid from grape seed oil, moistures the skin, aids in the healing of sunburns and may reduce *Acne vulgaris* (Vermaak et al., 2011).

Similar to known applications of Bioflavia's products, grape pomace can be used as a functional food due to its high fiber and phenolic content. Both have demonstrated beneficial effects regarding human health. Dietary fiber regulates glucose absorption, prevents constipation and obesity, decreases blood cholesterol and reduces cardiovascular risk (González-Centeno, 2010). Studies have been performed to determine consumer acceptance for grape seed flour-containing products (RosalesSoto, Brown, & Ross, 2012). Grape seed flour was added to food products in varying concentrations (pancakes, noodles and cereal bars). The highest consumer acceptance, based on sensory evaluation, was the cereal bars containing 5% Merlot grape seed flour. Another study was performed with five tea infusions made from grape pomace skins (Pinot Noir and Pinot Gris) (Cheng et al., 2010). It was found that women had a higher acceptance towards the product after being told the beneficial health effects of grape skins. The higher acceptance was based on the increased purchase intention (29%). Consumers were also willing to pay a higher price given the presumed beneficial health effects (Cheng et al., 2010).

Although not bioactive applications, but none-the-less high value, grape pomace has also been shown to act as a very clean, environmentally-friendly reducing-, capping-, and stabilizing- agent and solvent in the production of metal nanoparticles (Baruwati & Varma, 2009), as a highly effective means of reducing pesticide leaching in soil (Marín-Benito et al., 2013), as a biosorbent material in the removal of heavy metals from water (Lasheen et al., 2013), as well as being the source of polyphenolics for the production of wood adhesives (Brahim, Gambier, & Brosse, 2014).

4. Discussion

Canadian viticulture is relatively small, but it is increasing annually and has become a very stable industry sector. In 2011, Ontario and B.C. produced approximately 21,804 tonnes of pomace (based on pomace constituting 25% of the original grape weight). This value varies due to the various viniculture techniques used. Currently, majority of the pomace produced in both provinces is either composted or converted to biogas. These applications are important, but there are many alternative applications that may be equally or more profitable.

The market potential for grape pomace based on Bioflavia's retail product as a reference is in the hundreds of millions of dollars, if 100% of the product is sold. A more economically sensitive study is needed to determine the market for supplements such a Bioflavia. This value was based solely on red grape skins and did not include any white skin pomace or any seeds. The market potential for grape seed oil based on PC grape seed oil's retail price is also in the millions; fully acknowledging that this value decreases due to a multitude of factors not considered in this paper.

The objective of this paper was to explore bioactive applications alternative to composting. Composting is an efficient method of adding beneficial nutrients to soil, but there are a significant number of variables involved in composting; especially grape pomace composting due to the high amount of phenolic compounds within. More research is needed to determine Canadian grape and soil compositions so that appropriate measures can be taken to determine the optimal amount of pomace compost to add to soils. This will ensure there is not an overabundance of nitrogen being added to vineyard soils and it will ensure grape pomace compost is not being wasted.

Future studies should observe the effects of extracting the bioactive compounds prior to composting. Extraction is more difficult when pomace is dried at high temperatures and composting may be more efficient with the removal of the phenolics and acids (Schieber et al., 2001).

The preliminary findings suggest there are alternative applications for grape pomacebioactives: functional foods, food processing, cosmetics, pharmaceutical and supplements. Until these applications are proven to be economically viable and profitable, grape pomace will continue to be mostly used as compost.

The market potential calculations in this paper are very crude and simply serve as a starting point due to the significant costs associated with every aspect of grape pomace production; from methods of vinification to soil properties. When the value 21,804 tonnes of pomace is given, there is no understanding of its sheer immensity due to the paucity of previous research in this area. Thus, the market potentials derived in this paper, although illustrating the maximum value; do however, hopefully provide a new perspective on potential profitability with alternate use given the amount of pomace that is produced. This is significant when Canada comprises only 0.2% of worldwide production.

As consumer demand for natural products continues to increase, and as we learn about more value-added applications for grape pomace utilization, one hopefully can see that there is a large market for grape pomace alternatives and the market would appear to be sustainably profitable given the promising future of Canadian viniculture (Figure 1).

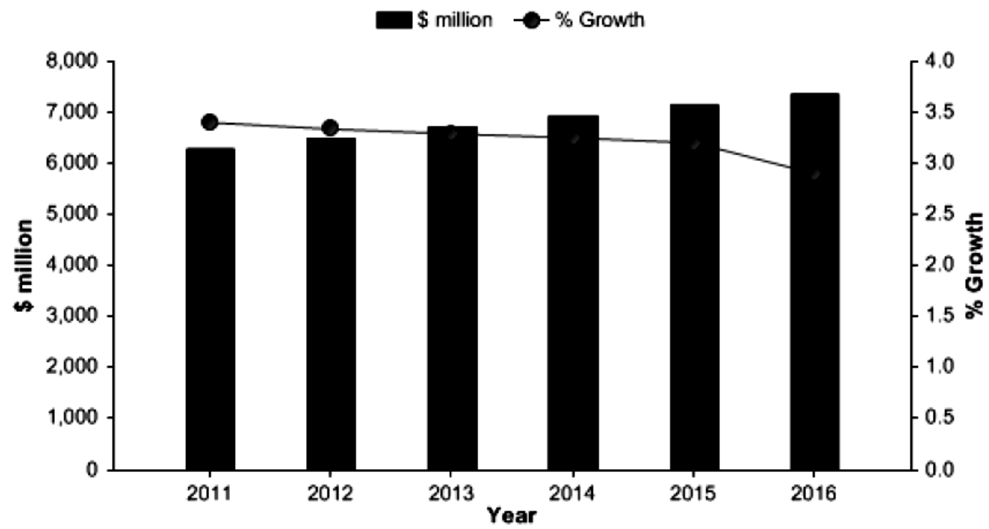

Figure 1. Future Canadian Wine Sales (Marketline Industry, 2012)

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