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Advance on the bioactivity and potential applications of dietary fibre from grape pomace

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ABSTRACT

The winemaking grape pomaces are rich in bioactive phytochemicals and dietary fibre (DF). DFs are phenolic-rich DF matrix and are dietary supplement with benefits on human health. As a result of the increased attention to sustainability of winemaking by-products, efforts have been made to use grape pomace in different bio-industries. In this review, we summarize the existing knowledge on the bioactivity and potential applications of DF from grape pomace, as well as the chemical compositions of DF. Furthermore, the biological activities of DF such as, anti-cancer activity, antibacterial activity, anti-inflammatory activity, antioxidant activity, improving gastrointestinal health activity, anti-apoptotic activity, preventing cardiovascular disease activity, anti-hypercholesterolemic activity, are discussed. Finally, the possible applications and future prospects of grape pomace DF in various fields are also summarised.

1. Introduction

Grapes (Vitis spp.) are one of the most valued conventional fruits in the world. There are about 60 species of grapes, most of which are found in the temperate zones of the Northern Hemisphere, distributed almost equally between Asia and America (Yang & Xiao, 2013). The grape belongs to the berry family as it is found attached to the stem. Grapes can be eaten raw or they can be used for making wine, jam, juice, jelly, grape seed extract, raisins, vinegar, and grape seed oil. The 80% of the grape yield is utilized for wine-making.

The wine-making industries produce millions of tons of residues (grape pomace) after fermentation, which represents a waste management issue both ecologically and economically (Fontana, Antoniolli, & Bottini, 2013). The productive use of such by-products could offer substantial economic benefits.

Most grape dietary fibre (DF) and phenolics accumulate in the fruit skins, seed and pulp, which after the manufacture of grape juice and wine remains as pomace or marc. As a matter of fact, grape pomace consists of three different components: seeds, stems, and skins. After production, this processed raw material becomes a by-product (Sánchez-Tena et al., 2013). Since grape pomace still contain large amounts of secondary metabolites, uses other than as fertilisers and animal feed might be appropriate. Grape pomace is considered as a valuable by-product for oil extraction, antioxidant and antibacterial agent preparation. The grape pamace contain some active compounds, such as, DF (Yu & Ahmedna, 2013), polyphenols (Deng, Penner, & Zhao, 2011), anthocyanins and flavonols (Downey, Mazza, & Krstic, 2007), and resveratrol (Yang, Martinson, & Liu, 2009).

DF has been consumed for centuries and has been recognised as contributing almost no energy and having health benefits (Tungland & Meyer, 2002). Currently, plants with DF and bioactive compounds are of growing interest to researchers because of their linkage to human health. Many prospective cohort studies have documented the significant health benefits of DF (Anderson & Jhaveri, 2012).

Indeed, grape pomace DF is a phenolic-rich DF matrix and is a dietary supplement that combines the benefits of both fibre and antioxidants help to prevent cancer and cardiovascular diseases. Herein, this review commences with the recent insights gained on the extraction, estimation and chemical composition of DF from grape pomace. This is followed by a discussion of biological activities of DF. And some potential applications in various fields are also summarized.

Abbreviations: GADF, grape antioxidant dietary fibre; MIC, minimal inhibition concentration; DPPH, 2,2-diphenyl-1-picrylhydrazyl radical; DF, dietary fibre; SDF, soluble dietary fibre; TDF, total dietary fibre; IDF, insoluble dietary fibre; WGP, wine grape pomace; NEPAs, non-extractable proanthocyanidins; GSE, grape seed extract; PCP, primary cardiovascular disease prevention; LDL, low-density lipoprotein; FRAP, ferric reducing antioxidant power; DM, dry matter; IBD, inflammatory bowel disease.

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2. Composition of grape pomace DF

2.1. Extraction of DF from grape pomace

The extraction of medicinal or functional compounds from natural materials, especially plant origin, is an important unit operation in food and bio-industries. Furthermore, the extraction of pharmaceutical compounds from plant has attracted the attention of researchers and industries due to the increasing market demands. Generally speaking, the extraction of DF can be classified into three main types: One is a conventional solvent extraction method; second uses microwave or ultrasonic to extract DF; third is enzyme-assisted extraction method. Microwave-assisted extraction and ultrasonic-assisted extraction widely used in the extraction of bioactive compounds, provides a rapid sample preparation with reduced amounts of solvent. Ferreira, de Pinho, and Cabral (2013) investigated the obtainment of SDF from white grape pomace *Chardonnay*, and showed that a hot aqueous extraction, 90 °C, ratio substrate/solvent of 1:4 and no gridding of the grape pomace was able to extract a great variety of polysaccharides, which were concentrated through membranes, enriching the diversity of SDF in the sample.

Enzyme-assisted extraction methods are gaining more attention because of the need for eco-friendly extraction (Puri, Sharma, & Barrow, 2012). Du, Li, Fan, and Zhu (2011) optimized the extraction of soluble dietary fibre (SDF) from grape pomace with hydrochloric acid using mathematical modelling based on Box–Behnken experimental design and multiple regression analysis. The optimal conditions for SDF extraction were 0.40 mol L^{-1} hydrochloric acid for extraction solvent at a ratio substrate/solvent of 1:12 (g mL^{-1}) under 75 °C for an extraction time of 90 min. Under the optimal extraction conditions, the yield of SDF was up to 47.56 mg g^{-1}, which was close to the model-predicted value.

2.2. Chemical composition of DF from grape pomace

Several methods are available for the measurement of DF in plant and food products. DF estimation was using the AOAC enzymatic–gravimetric method (AOAC., 2005). For non-starch-containing samples, AOAC method 2009.01 can be replaced by 985.29, with inclusion of the measurement of SDF. In addition, only AOAC methods 2009.01 and 2011.25 give measurement of all fibre components as defined by Codex Alimentarius (McCleary, Sloane, Draga, & Lazewska, 2013). Samples are gelatinized with Termamyl, and then enzymatically digested with protease and amyloglucosidase to remove protein and starch. Four volumes of ethyl alcohol are added to precipitate SDF. Total residue is filtered, washed with 78% ethyl alcohol, 95% ethyl alcohol, and acetone. After drying, residue is weighed. One duplicate is analysed for protein, and other is incinerated at 525 °C and ash is determined. Total dietary fiber = weight residue − weight (protein + ash) (AOAC, 2005). A method for the determination of IDF, SDF, and TDF, as defined by the CODEX Alimentarius, was validated in foods. Based upon the principles of AOAC Official Methods 985.29, the method quantitates water-insoluble and water-soluble DF (McCleary et al., 2012). TDF is calculated as the sum of IDF and SDF. Deng et al. (2011) measured the DF from two white wine grape pomace and three red wine grape pomace by gravimetric-enzymatic method with sugar profiling by high performance liquid chromatography-evaporation light-scattering detection. Recent development in DF methodology has adopted another general approach – enzymatic-chemical method. This method involves enzymic removal of starch, precipitation with 80% (v/v) ethanol to separate the SDF polysaccharides from low molecular weight sugars and starch hydrolysis products. These approved methods gave the analyst an overabundance of valid choices to measure total dietary fibre (TDF). The fact that each method will give a different result can tempt to select the most profitable method for the task at hand. Scientifically, it has generally been an understanding about which carbohydrates constitute DF, based on their composition and their physiological effects. It was reported that DF content of grape pomace was more than 60%. The content of the chemical composition of DF fractions of grape pomace was reported. 80% of dry matter (DM) was analysed as TDF and insoluble dietary fibre (IDF) was the main fraction. It has also observed that 90% of the neutral sugars were in IDF but the pectin substances were equally distributed in both IDF and SDF. Neutral sugar composition was determined by gas chromatography of alditol acetates (Cabotaje, López-Guisa, Shinnick, & Marlett, 1990). In the study of Deng et al. (2011), IDF composed of Klason lignin (7.9–36.1% DM), neutral sugars (4.9–14.6% DM), and uronic acid (3.6–8.5% DM) weighed more than 95.5% of TDF in all white and red wine grape pomace varieties. White wine grape pomace was significantly lower in DF (17.3–28.0% DM) than those of red wine grape pomace (51.1–56.3%), but extremely higher in soluble sugar (55.8–77.5% DM vs. 1.3–1.7% DM) ($p < 0.05$). Llobera and Cañellas (2007) determined the general composition of pomace and stem of the Manto Negro red grape (*Vitis vinifera*) variety. Both pomace and stem present high contents of TDF, comprising three fourths of the total DM. Due to the high fibre content, the SDF, IDF, uronic acids and Klason lignin were analysed in both samples. The chemical composition of grape pomace was showed in Table 1.

3. Biological activities of grape pomace DF

DF is generally accepted as having protective effects against a range of diseases predominant in developed countries. Moreover, DF that inhibit intestinal digestive processes result in decreased

Table 1
The chemical composition of grape pomace from different varieties.*

Varieties	Manto Negro (Llobera & Cañellas, 2007)	Muller Thurgau (Deng et al., 2011)	Morio Muscat (Deng et al., 2011)	Cabernet Sauvignon (Deng et al., 2011)	Merlot (Deng et al., 2011)	Pinot Noir (Deng et al., 2011)
Protein	12.2 ± 0.29	6.54	5.38	12.34	11.26	12.13
Fat	–	2.64	1.14	6.33	3.35	4.74
Soluble sugars	3.27 ± 0.10	55.77 ± 2.12	77.53 ± 1.01	1.71 ± 0.49	1.34 ± 0.92	1.38 ± 0.93
Oil	13.53 ± 0.23	–	–	–	–	–
Ash	5.50 ± 0.14	2.53	3.31	7.59	7.19	6.17
Soluble pectins	6.20 ± 0.30	–	–	–	–	–
Condensed tannins	22.3 ± 1.36	–	–	–	–	–
TDF	74.5 ± 2.43	28.01 ± 1.36	17.28 ± 0.21	53.21 ± 0.38	51.09 ± 0.58	56.31 ± 1.47
IDF	63.7 ± 2.12	27.29 ± 1.46	16.44 ± 0.24	52.40 ± 0.40	49.59 ± 0.34	54.59 ± 1.57
SDF	10.8 ± 0.30	0.72 ± 0.14	0.84 ± 0.07	0.81 ± 0.06	1.51 ± 0.14	1.72 ± 0.15

* TDF: total dietary fibre; IDF: insoluble dietary fibre; SDF: soluble dietary fibre.