concentration of metal ions in juice and wine (Tariba 2011, Fabjanowicz and Płotka-Wasylka 2021, Gajek et al. 2021). Extensive research on still wines has demonstrated the application of trace metal profiles and stable isotope ratios to regionally fingerprint wines for the purposes of tracing quality and authenticating geographic origin (Almeida et al. 2003, Coetzee and Vanhaecke 2005, Rodrigues et al. 2011, Bora et al. 2018, Rodrigues et al. 2020, Gajek et al. 2021).

In addition to metal levels derived from the growing site, anthropogenic input during winemaking can introduce or modify levels of individual metals, thereby altering the metal composition during the processing of grapes from juice to wine. Total metal levels generally decrease during fermentation and aging due to their precipitation or coprecipitation with suspended solids (Almeida et al. 2003). Furthermore, wine quality parameters are closely linked to metal ion levels, which can influence yeast nutrition during fermentation, redox processes, haze formation, color stability, acidity, and off-flavor development (Esparza et al. 2005, Tariba 2011, Viviers et al. 2013, Morozova et al. 2014). For example, increased levels of Cu, aluminum (Al), iron (Fe), nickel (Ni), and zinc (Zn) can form tannin and protein haze complexes (Esparza et al. 2005), generating undesirable sensory and color changes in the wine. Also, high levels of Cu(II) and Fe(III) ions in wine (above 1 and 7 mg/L, respectively) can impart bitter and metallic tastes (Tariba 2011, Morozova et al. 2014).

Although the metal composition of red and white still wines has been extensively investigated within winemaking regions and across different grape varieties, sparkling wine remains relatively underexamined. Sparkling wine is an expanding market that accounts for ~7% of global wine production (International Organisation of Vine and Wine 2020). The Niagara Peninsula in Canada’s province of Ontario is the country’s largest viticultural area, containing two regional appellations and 10 subappellations regulated and administeouV’)(2".8 (n)5.3 (i)-222 (u)-27.d[(iQ-6.4 (l ud)0.587 (n)-92 (u)-12.8 (n)927.1 (n)5.3 (y.8))-2A1.7t.4

Table 1

metal content compared to white sparkling wines due to the maceration process, which extracts metals localized in grape skin and seed structures (Pérez Cid et al. 2019).

(USEPA 1994). B analysis by ICP-OES was carried out per the USEPA Method 6010D for trace elements in aqueous solutions (USEPA 2018).

Wines were sampled directly from freshly opened bottles, transferred to 15-mL sterile conical tubes (VWR), and stored at 4°C for two to three weeks until analysis. Single bottles of each wine were evaluated, consistent with previous studies that surveyed metal composition of wines (Cabrera-Vique et al. 1997, Teissedre et al. 1998, Jos et al. 2004b, Paustenbach et al. 2016, Gajek et al. 2021). All wine samples were analyzed in duplicate. Samples were degassed and diluted tenfold by diluting 2.5 mL wine to 25 mL with ultrapure deionized water. Samples (25 mL, as prepared) and quality control solutions (blanks, duplicates, and reference solutions) were measured into DigiTubes (SCP Science) with 0.25 mL concentrated trace-grade HNO_3 and 0.125 mL concentrated HCl for digestion at 90°C for 240 min. This dilution and digestion were intended to reduce matrix e f ects associated with organic and inorganic compounds in the wine (Moehring and Harrington 2021). Samples were cooled and diluted to 25 mL with double-deionized water and analyzed by ICP-MS and/or ICP-OES. This method of preparation, including digestion, was carried out for all method blanks, duplicates, and certi-

individual secondary fermentation is carried out in each bot-

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