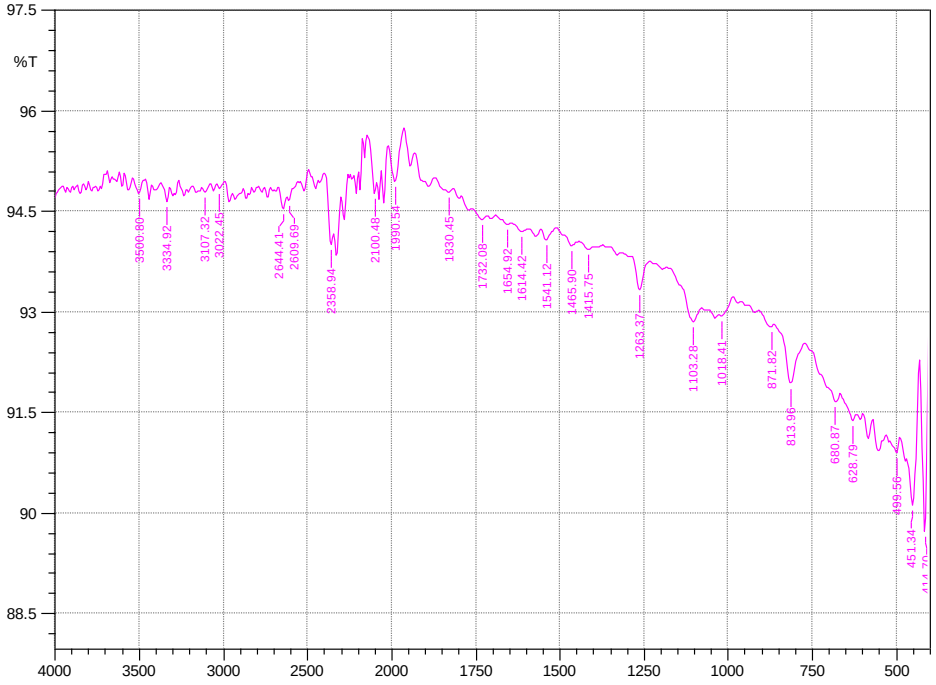

Figure S1. FTIR spectra of the tinplate surface after immersion for 12 hours at 25 °C in 3 % NaCl with 0.6 g/L sage extract inhibitor.

Characterization of the protective adsorption layer on the tinplate surface using ATR-FTIR analysis

Attenuated total reflectance (ATR-FTIR) analysis was used to confirm the presence of some functional groups in the prepared protective layer formed on the tinplate surface after exposure to the corrosive medium of 3% sodium chloride solution containing 0.6 g/L sage extract for 2.5 hours (Figure S1). The bands at 3500, 3334 and 3107 cm^{-1} correspond to the O-H stretching vibrations. The bands at 2644, 2609, 2358, 2100, and 1990 cm^{-1} are associated with aliphatic C-H stretching of CH, CH_2 and CH_3, respectively. The evolution peaks at 1830, 1732, 1654, and 1614 cm^{-1} are due to C=O in carbonyl group, C=C stretching vibrations in $C=CH_2$, CH=CH, and CH=C alkyl groups. The peaks at 1541, 1465, 1415, and 1263 cm^{-1} are attributed to the absorption of C-H bending vibrations of CH_3 and CH_2 groups, C-O stretching vibrations, symetric $CH_3(CO)$ bending and C-O-C stretching vibrations. The peak at 1103, cm^{-1} is attributed to C-OH stretching vibrations and 1018 cm^{-1} to C-O stretching vibrations of phenols or alcohols [51]. The peaks between 400 and 900 cm^{-1} could be attributed to the stretching vibrations of metal oxides, as found in studies [21,22]. The FTIR spectrum shows that the sage extract contains a mixture of compounds, i.e. polyphenols, fatty acids, mono- and diterpenes. The presence of O–H, C–H and C=O bonds is evident and indicates the presence of carboxylic acids. The phenolic components have heteroatoms such as N and O, which may serve as adsorption centres. These results indicate that the sage extract adsorbed on the tinplate surface contains O and N atoms in functional groups and aromatic rings, which is consistent with other authors [22,44,48]. Fang et al. [44] conducted a study in which the aromatic structure of the phenolic compounds was related to the corrosion inhibitory properties. From the FTIR characterization results, the reason for the corrosion inhibitory property of sage extract is the presence of O atoms in the aromatic rings of flavonoids; the band shift confirms that the sage extract inhibits corrosion by adsorption on the tinplate surface. Sage extract has not yet been used as an anti-corrosion agent for tinplate, but this research has shown that sage has good anti-corrosion properties for tinplate due to its chemical composition and high content of polyphenolic compounds. The effectiveness of sage extract in inhibiting the corrosion of tinplate is attributed to the synergistic effect of the organic molecules contained in the extract.