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Synthesis and Characterization of Organotin (IV) Complexes Derived of 3-(dimethylamino)benzoic Acid: *In vitro* Antibacterial Screening Activity

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Abstract: Organotin(IV) carboxylate complexes derivative of 3-(dimethylamino)benzoic acid, 3-$[N(CH_3)_2]C_6H_4COOH$ have been successfully synthesized. Two types of diorganotin(IV) complexes, $[\{3\text{-}[N(CH_3)_2]C_6H_4COO(R)_2Sn\}_2O]_2$ dimer (R= methyl **1**, butyl **3**) and $\{3\text{-}[N(CH_3)_2]C_6H_4COO\}_2(C_4H_9)_2Sn$, **2** (monomer) as well as 3-$[N(CH_3)_2]C_6H_4COO(C_6H_5)_3Sn$, **4** were successfully synthesized and obtained in solid state. The acid and complexes **1** – **4** obtained were characterized quantitatively using C, H, N and Sn elemental analysis as well as spectroscopic methods such as infrared (FTIR) and nuclear magnetic resonance (^1H, ^{13}C, ^1H-^{13}C HMQC & ^{119}Sn NMR). Infrared spectroscopy showed that the coordination took place via oxygen atoms from the carboxylate anions. From ^{13}C NMR spectroscopy data, the δ(COO) of complexes **1-4** are shifted to lower field compared to the parent acid indicated the coordination of carboxylate anion to the tin atom moiety. Moreover, the complexes obtained were screened for their *in vitro* antibacterial activity. Complex **4** was found to be most active against *Bacillus subtilis* and *Staphylococcus aureus* bacterial strains compared to complexes **1-3**.

Key words: Organotin(IV) carboxylate, *In vitro* antibacterial screening activity

INTRODUCTION

The chemistry of organotin complexes was explored more than a hundred years ago. Lowig prepared the first organotin compound in 1852 (Evans and Karpel, 1985). However, Sir Edward Frankland (1825-1899) carried out the detailed studies of organotin. Sir Edward Frankland prepared diethyltin diiodide (1853) and tetraethyltin (1859) and he gained credit of the first comprehensive study of organotin (Evans and Karpel, 1985). Even after the discovery of organotin nearly a century, the interest and studies of organotins remained as laboratory curiosities. From 1950s onwards, organotin(IV) carboxylate complexes became commercially relevant when the polyvinyl chloride (PVC) industry began to expand tremendously (Blunden *et al*., 1985; Evans and Karpel, 1985). From that time onwards, organotin(IV) carboxylate compounds received considerable attention due to the large array of applications in industries as well as due to their biocidal properties (Molloy *et al*., 1984; Qiang *et al*., 1998; Gielen *et al*., 2000; Tamai *et al*., 2001; Ronconi *et al*., 2002; Han and Yang, 2002; Arkiş and Balköse, 2005). Up to date, organotin(IV) complexes are still extensively studied due to its coordination geometries as well as structural diversity such as monomer, dimeric, hexameric and oligomeric (Zhang *et al*., 2005; Win *et al*., 2007; 2008a; Amini *et al*., 2009).

In this paper, we are focus on synthesis and structural characterization of new organotin(IV) carboxylate complexes derived from 3-(dimethylamino)benzoic acid. In addition, the *in vitro* antibacterial screening activities of the complexes obtained are carried out and the results are reported herein.

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MATERIALS AND METHODS

***General and Instrumental*:**

Triphenyltin(IV) hydroxide, Ph_3SnOH was purchased from Aldrich Chemical. Dibutyltin(IV) oxide, Bu_2SnO, dimethyltin(IV) dichloride, Me_2SnCl_2 and 3-(dimethylamino)benzoic acid, 3-$[N(CH_3)_2]C_6H_4COOH$ were obtained from Fluka Chemika. All the reagents, starting materials as well as the solvents are purchased commercially and used without any further purification. The melting points were determined in an open capillary and are uncorrected. Elemental C, H and N analyses were carried out on a Perkin-Elmer 2400 CHN Elemental Analyzer. Tin was determined gravimetrically by igniting a known quantity of each complex to SnO_2. Infrared spectra were recorded using a Perkin-Elmer System 2000 FTIR Spectrophotometer as a KBr disc in the frequency range of 4000-400 cm^{-1}. The spectra for ^1H, ^1H-^{13}C HMQC and ^{119}Sn NMR were recorded on a Bruker AC-P 400 MHz FTNMR Spectrometer and ^{13}C NMR was recorded on a Bruker AC-P 300MHz FTNMR Spectrometer using deuterated $CDCl_3$ as the solvent and tetramethylsilane, TMS as the internal standard.

***Preparation of Dimethyltin(IV) Oxide, Me_2SnO and Salt*:**

The sodium salt of the acid was obtained by heating under reflux a 1:1 molar mixture of sodium hydroxide, NaOH (0.12 g, 3 mmole) and 3-(dimethylamino)benzoic acid, 3-$[N(CH_3)_2]C_6H_4COOH$ (0.50 g, 3 mmole) in ethanol (50 mL) for two hours. After a few days, brown precipitates were obtained. Dimethyltin(IV) dichloride, Me_2SnCl_2 was dissolve in distilled water and stirred overnight which later gave colourless solution. Ammonia solution (60%) was added into the colourless solution and finally fine white precipitates were obtained, filtered and dried in oven (60 °C) for a day.

Preparation of Organotin(IV) Complexes:

Bis[3-(dimethylamino)benzoato]tetramethyldistannoxane(IV) dimer, $[\{3\text{-}[N(CH_3)_2]C_6H_4COO(CH_3)_2Sn\}_2O]_2$ (**1**)

Complex **1** was obtained by heating under reflux a 1:2 molar mixture of dimethyltin(IV) oxide (0.49 g, 3 mmole) and 3-(dimethylamino)benzoic acid (0.99 g, 6 mmole) in methanol (50 mL) for two hours. A clear brown transparent solution was isolated by filtration and kept in a bottle. After few days, brown solids (0.59 g, 61.3 % yield) were collected. M.p.: 246.3-247.8 °C. Analysis for $C_{44}H_{64}N_4O_{10}Sn_4$: C, 41.11; H, 5.02; N, 4.23; Sn, 36.50 %. Calculated for $C_{44}H_{64}N_4O_{10}Sn_4$: C, 41.17; H, 5.03; N, 4.36; Sn, 36.98 %. FTIR as KBr disc (cm^{-1}): ν(C-H) aromatic 3077, ν(C-H) saturated 2974, 2916, 2806; $\nu(COO)_{as}$ 1597, 1541; $\nu(COO)_s$ 1333, 1365; ν(C-N) 1235, ν(Sn-O-Sn) 658, ν(Sn-C) 575, ν(Sn-O) 426. ^1H-NMR (ppm) ($CDCl_3$): d: benzene protons 6.93 (d, 8.0 Hz, 4H); 7.33 (t, 7.6 Hz, 4H); 7.40 (d, 7.7 Hz, 8H); N-$(CH_3)_2$ 3.04 (s, 24H); methyl, CH_3 0.97 (s, 12H), 1.06 (s, 12H). ^{13}C-NMR (ppm) ($CDCl_3$): d: benzene carbons 113.70, 116.30, 118.05, 128.83, 133.66, 150.90; N-$(CH_3)_2$ 40.89; methyl 7.40, $^1J(^{119}Sn - ^{13}C)$= 779.3 Hz, 9.40 $^1J(^{119}Sn - ^{13}C)$= 795.3 Hz; COO 173.80. ^{119}Sn-NMR (ppm) ($CDCl_3$): d: -178.82, -183.19.

Bis{3-(dimethylamino)benzoato}dibutyltin(IV), $\{3\text{-}[N(CH_3)_2]C_6H_4COO\}_2(C_4H_9)_2Sn$ (**2**)

This complex was obtained by heating under reflux a 1:2 molar mixture of dibutyltin(IV) oxide, (0.75 g, 3 mmole) and 3-(dimethylamino)benzoic acid, (0.99 g, 6 mmole) in acetonitrile (60 mL) for four hours. A clear brown solution was separated by filtration and kept in a bottle. After two weeks, some brown crystals (1.31 g, 74.0 % yield) were collected. Melting point: 113.3-114.1 °C. Analysis for $C_{26}H_{38}N_2O_4Sn$: C, 55.63; H, 6.77; N, 4.90; Sn, 20.75 %. Calculated for $C_{26}H_{38}N_2O_4Sn$: C, 55.64; H, 6.82; N, 4.99; Sn, 21.15 %. FTIR as KBr disc (cm^{-1}): ν(C-H) aromatic 3083, ν(C-H) saturated 2953, 2925, 2868, 2808; $\nu(COO)_{as}$ 1608, $\nu(COO)_s$ 1360, ν(C-N) 1231, ν(O-Sn-O) 679, ν(Sn-C) 551, ν(Sn-O) 459. ^1H-NMR (ppm) ($CDCl_3$): d: benzene protons 6.94 (dd, 2.4 Hz, 7.9 Hz, 2H); 7.33 (t, 8.0 Hz, 2H); 7.50 (d, 8.5 Hz, 4H); N-$(CH_3)_2$ 3.01 (s, 12H); butyl, CH_3 0.88 (t, 7.3 Hz, 6H); CH_2 1.34-1.44 (m, 4H); CH_2 1.69-1.84 (m, 8H). ^{13}C-NMR (ppm) ($CDCl_3$): d: benzene carbons 114.42, 117.40, 119.02, 129.36, 131.09, 150.86; N-$(CH_3)_2$ 41.02; butyl 13.98, 25.85, 26.82, 27.11; COO 177.25. ^{119}Sn-NMR (ppm) ($CDCl_3$): d: -156.40.

Bis[3-(dimethylamino)benzoato]tetrabutyldistannoxane(IV) dimer, $[\{3\text{-}[N(CH_3)_2]C_6H_4COO(C_4H_9)_2Sn\}_2O]_2$ (**3**)

This title complex was prepared by similar method to those described for complex **1**, except substituting with Bu_2SnO and the reaction was heating under reflux for three hours. After five days, brown crystals (2.14 g, 66.1 % yield) were collected. M.p.: 137.3-138.2 °C. Analysis for $C_{68}H_{112}N_4O_{10}Sn_4$: C, 50.62; H, 6.52; N,

3.44; Sn, 29.53 %. Calculated for $C_{68}H_{112}N_4O_{10}Sn_4$: C, 50.40; H, 6.97; N, 3.46; Sn, 29.30 %. FTIR as KBr disc (cm^{-1}): ν(C-H) aromatic 3075, 3030; ν(C-H) saturated 2956, 2924, 2870, 2855; $\nu(COO)_{as}$ 1595, 1573; $\nu(COO)_s$ 1330, 1368; ν(C-N) 1237, ν(Sn-O-Sn) 635, ν(Sn-C) 572, ν(Sn-O) 420. ^{1}H-NMR (ppm) ($CDCl_3$): d: benzene protons 6.94 (d, 6.8 Hz, 4H); 7.34 (t, 7.3 Hz, 4H); 7.43 (d, 7.5 Hz, 8H); N-$(CH_3)_2$ 3.04 (s, 24H); butyl, CH_3 0.81-0.93 (m, 24H); CH_2 1.32-1.45 (m, 16H); CH_2 1.71-1.78 (m, 32H). ^{13}C-NMR (ppm) ($CDCl_3$): d: benzene carbons 114.29, 116.42, 118.58, 129.11, 131.52, 150.90; N-$(CH_3)_2$ 41.09; butyl 14.04, 26.84, 27.26, 27.96, 28.24, 29.06, 30.99; COO 173.79. ^{119}Sn-NMR (ppm) ($CDCl_3$): d: -195.35, -207.95.

3-(Dimethylamino)benzoatotriphenyltin(IV), 3-$[N(CH_3)_2]C_6H_4COO(C_6H_5)_3Sn$ (**4**)

Complex **4** was prepared by heating under reflux a 1:1 molar mixture of triphenyltin(IV) hydroxide (1.10 g, 3 mmole) and 3-(dimethylamino)benzoic acid (0.50 g, 3 mmole) in acetonitrile (50 mL) for two hours. Clear brown solution was isolated by filtration and kept in a bottle. After eight days, brown crystals (1.01 g, 65.7 % yield) were collected. Melting point: 140.2-141.5 °C. Analysis for $C_{27}H_{25}N_1O_2Sn$: C, 63.05; H, 4.91; N, 2.67; Sn, 23.00 %. Calculated for $C_{27}H_{25}N_1O_2Sn$: C, 63.07; H, 4.90; N, 2.72; Sn, 23.08 %. FTIR as KBr disc (cm^{-1}): ν(C-H) aromatic 3065, 3051, 3026; ν(C-H) saturated 2989, 2908, 2810; $\nu(COO)_{as}$ 1625, $\nu(COO)_s$ 1322, ν(C-N) 1227, ν(Sn-O) 445. ^{1}H-NMR (ppm) ($CDCl_3$): d: phenyl protons 7.42-7.49 (m, 9H); 7.79-7.81 (m, 6H); benzene 6.87 (dd, 2.7 Hz, 8.3 Hz, 1H); 7.26 (t, 7.8 Hz, 1H); 7.52 (d, 7.6 Hz, 2H); N-$(CH_3)_2$ 2.95 (s, 6H). ^{13}C-NMR (ppm) ($CDCl_3$): d: phenyl carbons C_{ipso} 139.01 (648.9 Hz), C_{ortho} 137.36 (47.9 Hz), C_{meta} 129.31 (63.2 Hz), C_{para} 130.28; benzene 114.84, 117.18, 119.31, 129.57, 134.59, 150.85; N-$(CH_3)_2$ 41.04; COO 174.05. ^{119}Sn-NMR (ppm) ($CDCl_3$): d: -114.19.

In vitro Antibacterial Screening Activity:

The synthesized complexes and parent acid were screened for their *in vitro* antibacterial activity against three gram-negative (*Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*) and two gram-positive (*Bacillus subtilis* and *Staphylococcus aureus*) bacterial strains, by Inhibition Zone Method using agar well diffusion method. The seeded agar (nutrient agar medium) was prepared by cooling the molten agar to 40 °C and then adding bacterial inoculums containing approximately 10^4-10^6 colony forming units (CFU)/mL. The bacterial inoculums were spread on the plate containing agar medium and even coverage was ensured before the agar solidified. The complexes were dissolved in DMSO to prepare 1.0 mg/mL concentration. By using a sterile metallic borer, the wells (6 mm in diameter) were dug and the standard drugs and complexes were introduced into the respective wells. The plates were incubated immediately at 37 °C for 20-24 hours. The activity was determined by measuring the diameter of the inhibition zone (in mm).

RESULT AND DISCUSSION

Physical and Elemental Analysis:

In this study, complexes **1 – 4** derived of 3-$[N(CH_3)_2]C_6H_4COOH$ have been obtained in solid state. Complexes **2** and **4** were obtained as single brown crystals and the X-ray crystal structure of both complexes have been reported (Win *et al*., 2007; 2008b). Elemental analysis C, H, N and Sn data obtained were in agreement with the predicted formula and complexes **1-4** gave a sharp melting point which indicate the isolation of fairly pure complexes. During the heating under reflux, molecular sieves and Dean-Stark apparatus were utilised to remove water formed during the reaction. An outline of the reaction scheme and proposed structure for complexes **1-4** are depicted in Figure 1. The melting points and elemental analytical data of complexes **1 – 4** are given in Table 1.

Table 1: Melting points and elemental analytical data (%) of complexes 1 – 4.

Complexes	Melting points	Elemental (%)			
		C	H	N	Sn
1	246.3 – 247.8	41.11 (41.17)	5.02 (5.03)	4.23 (4.36)	36.50 (36.98)
2	113.3 – 114.1	55.63 (55.64)	6.77 (6.82)	4.90 (4.99)	20.75 (21.15)
3	137.3 – 138.2	50.62 (50.40)	6.52 (6.97)	3.44 (3.46)	29.53 (29.30)
4	140.2 – 141.5	63.05 (63.07)	4.91 (4.90)	2.67 (2.72)	23.00 (23.08)

Calculated value are given in parentheses

Infrared Spectroscopy:

The characteristic infrared absorption frequencies (cm^{-1}) and assignments of important absorption bands of the acid, sodium salt and complexes **1 – 4** are listed in Table 2. The assignments of the absorption bands

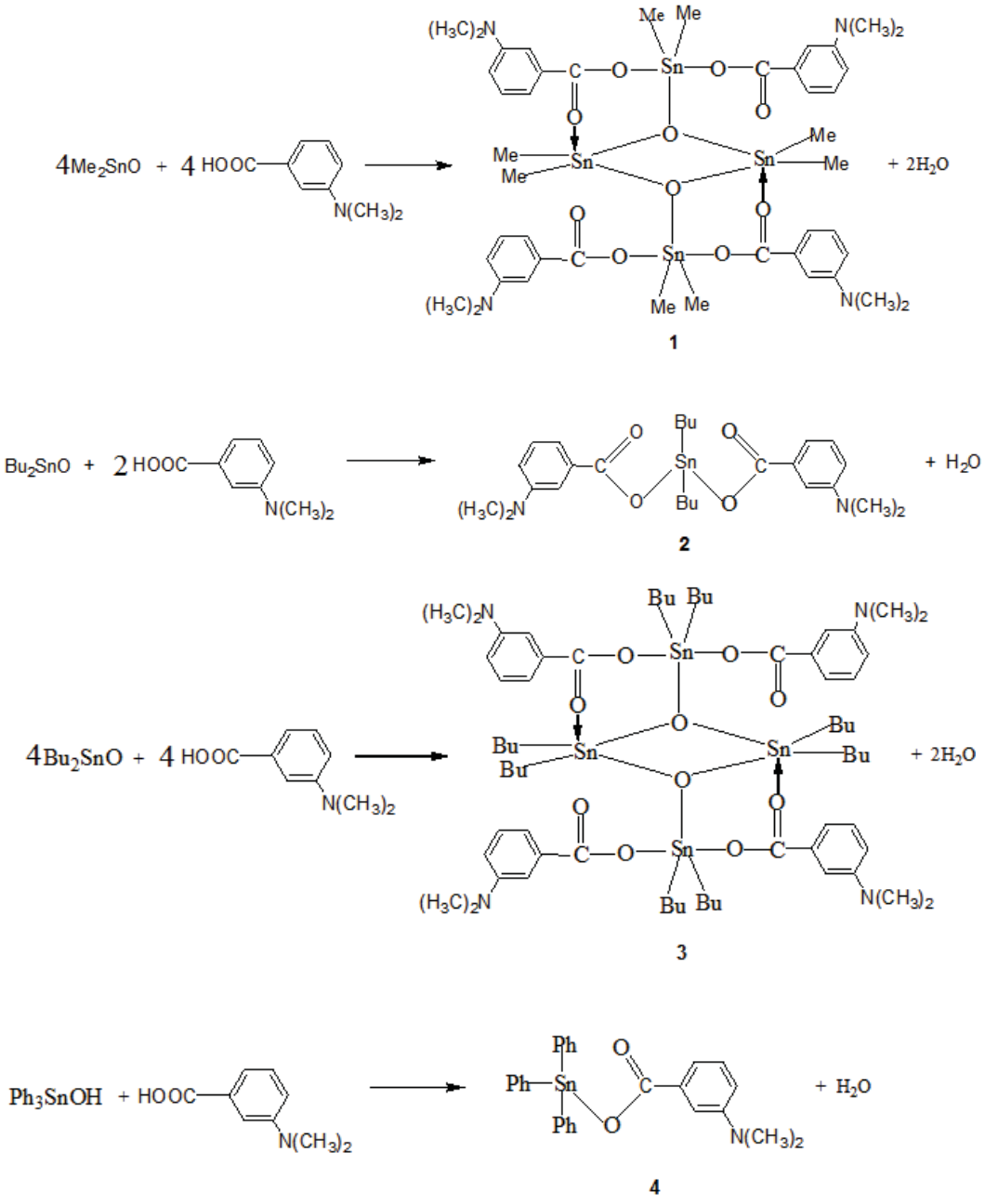


Fig. 1: An outline of the reaction scheme and proposed structure for complexes **1-4**.

for complexes **1 – 4** were made upon comparison with the infrared spectra of the parent acid and their sodium salt. Complexes **1 – 4** revealed the presence of the ν(C-N) (1237-1227 cm^{-1}) bands which were also present in 3-(dimethylamino)benzoic [ν(C-N)= 1268 cm^{-1}] without any significant difference indicating that the C-N functional group does not play a role in the coordination to tin atom moiety. In addition, this finding also confirmed by the X-ray crystal structures of complexes **2** and **4** (Win *et al*., 2007; 2008b). The ν(O-H) bands which appeared in the range 2885-2544 cm^{-1} for the acid, were absent in the infrared spectra of salt and

complexes **1-4** also showed the deprotonation and coordination of the carboxylate anion. The infrared spectra of complexes **1-4** revealed that the $\nu(COO)_{as}$ was shifted to a lower wave length number compared to the parent acid which signify that the coordination took place via the oxygen atoms of the carboxylate anion. Complexes **1-4** showed the $\nu(COO)_{as}$ and $\nu(COO)_s$ are in the range of 1605-1579 and 1394-1347 cm^{-1} respectively.

The magnitude of $\Delta\nu = [\nu(COO)_{as} - \nu(COO)_s]$ is a useful indicator in the correlation of the coordination modes of the carboxylate anion to the tin atoms. Sandhu and Verma have shown that the $\Delta\nu$ value of complexes greater by 65-90 cm^{-1} than in their sodium salts indicates either asymmetric or monodentate bonding of the carboxylate group to tin(IV) atom (Sandhu and Verma, 1987). Complex **2** was isolated as a monomeric type and its $\Delta\nu$ value indicated that the carboxylate anions were bonded to tin atom moiety in a monodentate mode. Two $\Delta\nu$ values for the organodistannoxane dimer type complexes indicate that the carboxylate anions were coordinated to the tin atom moiety in either a monodentate or bidentate manner (Win *et al*., 2008a). For complex **1**, the first $\Delta\nu$ value (264 cm^{-1}) was larger than the $\Delta\nu$ value of the sodium salt while the second $\Delta\nu$ value (176 cm^{-1}) was comparable to the sodium salt (182 cm^{-1}). Hence a pair of carboxylate anions bonded to tin atom in monodentate manner and another pair of carboxylate anions bonded to tin atom in bidentate manner respectively resulting the tin atoms in complex **1** exhibited distorted trigonal bipyramid geometry. Complex **3** was also isolated as bulky organodistannoxane dimer types and were found to be similar to complex **1**. Moreover, for complexes derived from triphenyltin(IV) carboxylate, $\Delta\nu$ below 200 cm^{-1} would be expected for bridging or chelating carboxylates, but greater than 200 cm^{-1} for the monodentate bonding carboxylate anions (Yeap and Teoh, 2003). Hence, carboxylate anion in complex **4** would be expected to bond to the tin atom in monodentate manner since the $\Delta\nu$ above 200 cm^{-1}.

Table 2: Important infrared data of acid, salt and complexes 1-4

Complexes	Wavelength (cm^{-1})						
	ν(OH)	$\nu(COO)_{as}$	$\nu(COO)_s$	$\Delta\nu$	ν(Sn-O)	ν(O-Sn-O)/ ν(Sn-O-Sn)	ν(Sn-C)
Acid	2885 - 2544	1677	1360	317	-	-	-
salt	-	1569	1387	182	-	-	-
1	-	1597					
1541	1333						
1365	264						
176	426	658	575				
2	-	1608	1360	248	459	679	551
3	-	1595					
1573	1330						
1368	265						
205	420	635	572				
4	-	1625	1322	303	445	-	-

$\Delta\nu = \nu(COO)_{as} - \nu(COO)_s$

Further evidence for the coordination to Sn via O atoms was revealed by the presence of the Sn-O stretching bands in the spectra of complexes **1-4** in the region of 459-420 cm^{-1}. The carboxylate anion was bonded to the tin cation via *p*p-*p*p and *p*p-*d*p during complexation (Poller, 1970). Bonding via *p*p-*d*p occurred due to the transfer of a pair of electrons from the carbonyl group to the vacant 5*d* orbitals of the tin atom (Poller, 1970). The presence of a medium absorption band at 679-635 cm^{-1} in the infrared spectra of complex **1-3** was ascribed to ν(Sn-O-Sn)/ν(O-Sn-O) which further supported the coordination of the oxygen atoms to the tin atom moiety (Win *et al*., 2008a). Generally, ν(Sn-O-Sn) band was fit in the assignment of additional Sn-O bonding in organodistannoxane dimer type since the centrosymmetry of the complexs were occupied by Sn_2O_2 (complexes **1** and **3**).

^{1}H, ^{13}C and ^{119}Sn Spectroscopy:

The ^{1}H NMR spectral data of complexes **1-4** are summarized in Table 3, ^{13}C and ^{119}Sn NMR data are listed in Table 4. The ^{1}H NMR spectra of complexes **1-4** revealed similarities to their parent acid, 3-(dimethylamino)benzoic acid. The ^{1}H NMR spectrum of 3-(dimethylamino)benzoic acid exhibited three sets of signals at downfield region [7.00 ppm, 7.35 ppm and 7.54 ppm] with integration values of 1:1:2 which was also observed in the ^{1}H NMR spectra of complexes **1-4** arising from the aromatic protons of the benzene ring. The upfield regions of the ^{1}H NMR spectra of the complexes **1-3** showed the signal of the methyl and butyl protons in the range of 0.97 – 1.11 and 0.88-1.78 ppm respectively. Complexes **2** and **3** consisted of dibutyl groups (monomer and distannoxane dimer types) and found in the upfield region in the NMR spectra.

Theoretically, the butyl groups should exhibit four signals corresponding to the protons of butyl groups, with multiplicities of triplet, sextet, quintet and triplet with integration values of 3:2:2:2, respectively. However, these complexes only exhibited three sets of signals in the range of 0.81-0.93 ppm (CH_3, triplet or multiplet), 1.32-1.45 ppm (CH_2, multiplet) and 1.69-1.84 ppm (CH_2, multiplet) respectively, due to the methylene protons having very similar environment causing their signals to overlap with each other in the ^{1}H NMR spectra (Danish *et al*., 1995; Teoh *et al*., 1996a; 1996b). Complex **1** was derived from dimethyltin(IV) complexes and isolated as an organodistannoxane dimer type and exhibited two sharp singlets at 0.97 and 1.06 ppm which corresponded to the methyl groups attached to the tin atom moiety. For complex **4**, the occurrence of multiplets in the regions centering around d≈ 7.45 ppm and 7.80 ppm with integration values of 9:6 respectively were ascribed to the aromatic protons of the phenyl group (Sau and Holmes, 1981; Willem *et al*., 1997; Nath *et al*., 2006). Based on the integration values, the number of protons in complexes **1-4** were in accordance with the number of protons proposed and the complexes **1-4** obtained exhibited no additional resonances thus reflect the purity of the complexes.

The formation of the complexes were evident from the d(COO) value in the ^{13}C NMR spectra. All the complexes exhibited a d(COO) signal in the range of 173.80-177.25 ppm. The ^{13}C NMR spectra of complexes **1-4** showed that the chemical shift of the d(COO) signal in each complex was shifted downfield compared to that of their parent acids (173.29 ppm), indicating the participation of the carboxylate anions in the coordination to the tin(IV) atom (Win *et al*., 2007; 2008b). This phenomenon resulted from the decrease of the electron density in the carboxylate anions upon coordinated to the tin atom moiety during complexation. The occurrence of six resonances in the range of 114.11 – 150.90 ppm and a single resonance in the range of 40.89 – 41.09 ppm in the ^{13}C NMR spectra of the complexes and acid defined as benzene and -methylamino carbons signals respectively. Complex **1** (organodistannoxane dimer type) exhibited two sharp signals at 7.40 and 9.40 ppm indicating the presence of the methyl groups in the $SnMe_2$ moiety with ^1J(^{119}Sn-^{13}C) satellites values at 779.3 and 795.3 Hz. Together with the application of the Lockhart-Manders equation, [ï^{1}Jï= 11.4q - 875]; the C-Sn-C angles were 145.1 and 146.5° (Lockhart and Manders, 1986). With the help of the ^{119}Sn solution studies, the tin atoms in complex **1** were confirmed to be five-coordinated and each exhibited a distorted trigonal bipyramid geometry. Complexes **2** and **3** are derivative of dibutyltin(IV) showed the occurrence of CH_3 and CH_2 in the range of 13.98-14.04 and 25.85-30.99 ppm respectively (Danish *et al*., 1995; Win *et al*., 2008a). In addition, complex **3** exhibited two sets of butyl signals in ^{13}C NMR spectra which attributed to the butyl groups linked to the exo- and endo-cyclic tin atom respectively. Complex **4** revealed the chemical shifts of the d(^{13}C)$_{ipso}$ at 139.01 ppm indicative of a four-coordinated Sn atom (Holeček *et al*., 1983a; 1983b; Baul *et al*., 2001). Generally, the ^{13}C NMR spectra of the complexes obtain were found to exhibit no additional resonance and thus reflects the purity of the complexes.

The d(^{119}Sn) values define the region with different coordination number of the tin atom moiety and the d(^{119}Sn) values are summarized in Table 4. For diorganotin(IV) carboxylate complexes, the d(^{119}Sn) value for four-coordinated complexes fall in the range between +200 to -60 ppm; for five-coordinated complexes between -90 to -190 ppm and for six-coordinated complexes between -210 to -400 ppm (Holeček *et al*., 1986). Complex derivatives of the organodistannoxane dimer types usually exhibit two well resolved d(^{119}Sn) signals. These two low- and high-field resonances were respectively attributed to the exo- and endo-cyclic tin atoms (Danish *et al*., 1995). From Table 4, the exo- and endo-cyclic tin atoms in complexes **1** and **3** were five-coordinated respectively. This indicated that a pair of carboxylate anions was bonded to the tin atom in a monodentate manner while the other two carboxylate anions were bonded to the tin atoms (endo and exo-cyclic tin atom) in a bridging bidentate manner. As a result, all the tin atoms in complexes **1** and **3** were five-coordinated and exhibited a distorted trigonal bipyramid geometry.

Table 3: ^{1}H NMR data of acid and complexes 1-4.

Compounds	Chemical Shift, *d* (ppm)		
	Benzene	Amino-N(CH_3)$_2$	Sn-R (R= Me, Bu & Ph)
Acid	7.00 (d, 9.3 Hz, 1H) H4		
	7.35 (t, 8.1 Hz, 1H) H5		
	7.54 (d, 7.8 Hz, 2H) H2 & H6	3.03 (s, 6H) H*y*	-
1	6.93 (d, 8.0 Hz, 4H) H4		
	7.33 (t, 7.6 Hz, 4H) H5		0.97 (s, 12H) H*a*
	7.40 (d, 7.7 Hz, 8H) H2 & H6	3.04 (s, 24H) H*y*	1.06 (s, 12H) H*a*
2	6.94 (dd, 2.4 Hz, 7.9 Hz, 2H) H4		0.88 (t, 7.3 Hz, 6H) H*d*
	7.33 (t, 8.0 Hz, 2H) H5		1.34-1.44 *(m, 4H) H*c*
	7.50 (d, 8.5 Hz, 4H) H2 & H6	3.01 (s, 12H) H*y*	1.69-1.84 *(m, 8H) H*a* & H*b*

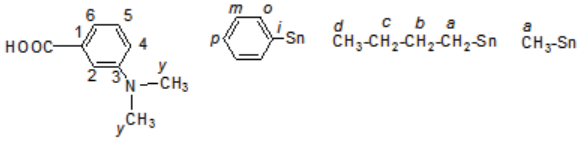
Table 3: Continue

3	6.94 (d, 6.8 Hz, 4H) H4		0.81-0.93 *(m, 24H) H*d*
	7.34 (t, 7.3 Hz, 4H) H5		1.32-1.45 *(m, 16H) H*c*
	7.43 (d, 7.5 Hz, 8H) H2 & H6	3.04 (s, 24H) H*y*	1.71-1.78 *(m, 32H) H*a* & H*b*
4	6.87 (dd, 2.7 Hz, 8.3 Hz, 1H) H4		
	7.26 (t, 7.8 Hz, 1H) H5		7.42-7.49 *(m, 9H) H*m* & H*p*
	7.52 (d, 7.6 Hz, 2H) H2 & H6	2.95 (s, 6H) H*y*	7.79-7.81 *(m, 6H) H*o*

s= singlet, d= doublet, t= triplet, dd= doublet of doublet, m= multiplet; *o*= ortho, *m*= meta, *p*= para; Coupling constant= Hz, *= overlap

Table 4: ^{119}Sn and ^{13}C NMR data of complexes 1-4.

Compounds	Chemical Shift (ppm)				
	^{119}Sn	Benzene	Amino N(CH_3)$_2$	Sn-R (R= Me, Bu & Ph) $^{n}J(^{119}Sn\text{-}^{13}C)$ (n=1, 2, 3 & 4)	COO
Acid	-	114.11 (C2), 118.06 (C4), 118.69 (C6), 129.53 (C5), 130.37 (C1), 150.87 (C3)	40.97 (C*y*)	-	173.29
1	-178.82 -183.19	113.70 (C2), 116.30 (C4), 118.05 (C6), 128.83 (C5), 133.66 (C1), 150.90 (C3)	40.89 (C*y*)	7.40 (^1J= 779.3 Hz) (C*a*) 9.40 (^1J= 795.3 Hz) (C*a*)	173.80
2	-156.40	114.42 (C2), 117.40 (C4), 119.02 (C6), 129.36 (C5), 131.09 (C1), 150.86 (C3)	41.02 (C*y*)	13.98 (C*d*), 25.85 (C*b*) 26.82 (C*c*), 27.11 (C*a*)	177.25
3	-195.35 -207.95	114.29 (C2), 116.42 (C4), 118.58 (C6), 129.11 (C5), 131.52 (C1), 150.90 (C3)	41.09 (C*y*)	14.04 (C*d*), 26.84 (C*c*), 27.26 (C*c*), 27.96 (C*b*), 28.24 (C*b*), 29.06 (C*a*), 30.99 (C*a*)	173.79
4	-114.19	114.84 (C2), 117.18 (C4), 119.31 (C6), 129.57 (C5), 134.59 (C1), 150.85 (C3)	41.04 (C*y*)	139.01 (^1J= 648.9 Hz) (C*i*), 137.36 (^2J= 47.9 Hz) (C*o*), 129.31 (^3J= 63.2 Hz) (C*m*), 130.51 (C*p*)	174.05



Complex **4** derivatives of triphenyltin(IV) exhibited d(^{119}Sn) values at -114.19 ppm which lie in the range of -40 to -120 ppm, hence, indicating that the tin atom in complexes **4** was four-coordinated and have a distorted tetrahedral geometry (Holeček *et al*., 1983a; Holeček *et al*., 1983b). From the ^{119}Sn NMR solution study, the tin atom of complex **2** was five-coordinated (predominantly). Moreover, based on the infrared spectroscopy and single crystal X-ray structure determination, complex **2** was pure and the tin atom was four-coordinated and existed in a distorted tetrahedral geometry (Win *et al*., 2007). This might be upon dilution, the crystal lattice were broken up resulting the carboxylate anions assembly self-arrangement (in dynamic state). Hence, one of the carboxylate anions was located close to the tin atoms and exhibited bidentate chelatation while the other carboxylate anion exhibited monodentate chelation resulting five-coordinated tin atom in complex **2**.

In vitro Antibacterial Screening Activity:

The *in vitro* antibacterial screening activity of parent acid and complexes **1-4** are given in Table 5. At 1.0 mg/mL, the antibacterial screening activity of organotin(IV) derivatives of 3-(dimethylamino)benzoic acid against *Bacillus subtilis* bacterial strain showed a general trend. The triphenyltin(IV) carboxylate complex (**4**= 16 mm) was found to be most active compared to the diorganotin(IV) carboxylate derivatives (**1**= 14 mm, **2**= 13mm and **3**= 10 mm) and this is in accordance with literature (Rehman *et al*., 2005; Shahid *et al*., 2006; Ahmad *et al*., 2007). This was also observed when complexes **1-4** were screened against *Staphylococcus aureus* strains. In this study, the tin atom moieties in complexes **4** was four-coordinated and exhibited tetrahedral geometry in solution form; hence causing the activities of complexes **4** to be greater compared to complexes **1-3** (Danish *et al*., 1995; Baul *et al*., 2002).

Conclusion:

Complexes **1-4** derivative of 3-(dimethylamino)benzoic acid have been successfully synthesized and characterized. Elemental analysis C, H, N and Sn data obtained were in agreement with the predicted formula. Results of the infrared and NMR spectroscopy on the acid and complexes showed that the coordination took place via oxygen atoms from the carboxylate group. As a result, in solid and liquid state, the tin atoms of complexes **1** and **3** are five-coordinated whereas four-coordinated in complex **4**. With the exceptional case, the tin atom in complex **2** is four-coordinated in solid state and exhibited five-coordinated in solution which may

attributed from the dynamic stage and self-rearrangement of one carboxylate anion. Based on the *in vitro* antibacterial screening activity, complex **4** showed significant activity on *Bacillus subtilis* and *Staphylococcus aureus* compared to complexes **1-3** but lower compared to reference drugs.

Table 5: *In vitro* antibacterial screening activity of parent acid and complexes 1-4

Complexes	Inhibition Zone (mm)				
	B. s.	E. c.	K. p.	P. a.	S. a.
Acid	13	7	7	11	13
1	14	13	16	13	14
2	13	9	9	12	12
3	10	7	8	10	9
4	16	7	-	-	20
Chloramphenicol	29	-	23	34	30
Doxycycline	34	24	21	40	28
Rifampicin	25	24	23	29	37

B.s.= *Bacillus subtilis*, E.c.= *Escherichia coli*, K.p. = *Klebsiella pneumoniae*, P.a. = *Pseudomonas aeruginosa*, S.a. = *Staphylococcus aureus*. Reference drug= Chloramphemicol, Doxycycline and Rifampicin
Agar well diffusion method (*in vitro*) = 1.0 mg/mL;

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