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PREPARATION OF 3-(n-ALKENOXY)PROPANOIC ACIDS.

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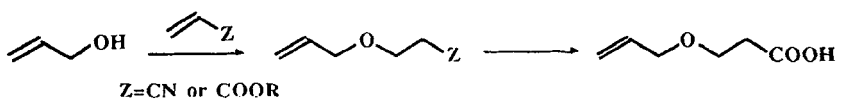
Abstract *: 3-(n-Alkenoxy)propanoic acids have been prepared by reaction of alkenols with tert-butyl acrylate (catalyzed by Triton B or n-butyl lithium) followed by cleavage of the tert-butyl group by CF_3COOH or KO_2.*

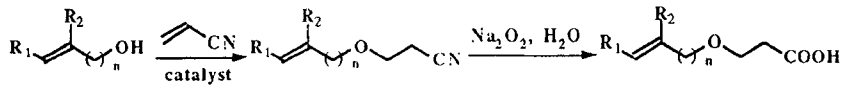
During our work on the electrophilic cyclization of alkenoic acids, in view of the synthesis of medium ring compounds [1], we need to obtain 3-(n-alkenoxy)propanoic acids. A straightforward method to prepare these compounds is to study the Michael addition of alkenols with acrylonitrile or acrylate, followed by hydrolysis of nitrile or ester functions.



Z=CN or COOR

This methodology has been applied to the preparation of 3-(2-propenoxy)propanoic acid. Reaction of allylic alcohol with acrylonitrile [2] gave in good yield Michael addition product which was hydrolyzed under acidic [3] (conc. HCl) or basic [4] (sodium hydroxide) conditions. However, this sequence cannot be generalized to other alcohols, due to either electrophilic addition of hydrogen chloride on the carbon-carbon double bond or basic catalyzed retro Michael reaction. To circumvent these problems, hydrolysis of 3-(n-alkenoxy)propionitriles was briefly reported using sodium peroxide in water.[5] We screened this method,

Table 1 : Preparation of 3-(n-alkenoxy)propanoic acids **3** via formation and hydrolysis of nitriles **2**.



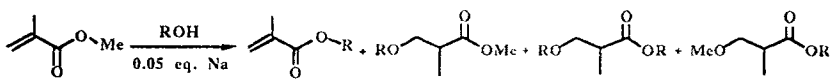
1 2 3

alkenols **1**	reaction time (h)	% Yield [a] **2**	reaction time (h)	% Yield [a] **3**
1a $R_1 = R_2 = H$, n = 1	(17)	91 **2a**	(46)	63 **3a**
1b $R_1 = H$, $R_2 = Me$, n = 1	(70)	67 **2b**	(50)	19 **3b**
1c $R_1 = Me$, $R_2 = H$, n = 1	(4)	90 **2c**	(70)	21 **3c**
1d $R_1 = R_2 = H$, n = 2	(18)	67 **2d**	(18)	38 **3d**
1e $R_1 = R_2 = H$, n = 3	(75)	52 **2e**	(24)	19 **3e**

[a] Refers to purified material.

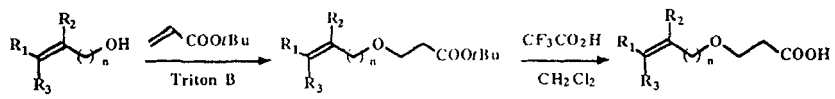
but with our substrates, except with parent compound **2a**, unsatisfactory yields were obtained (see Table 1). Other drawbacks of this method were large reaction times (for the two steps) and high solubility of acids in water, which necessitated a troublesome extraction.

The second method implies the Michael addition of alkenols with acrylates, followed by hydrolysis of the ester function. This pathway has not been yet explored, though the addition of alcoholates on methyl acrylate had been reported.[6] We reinvestigated this reaction and for example we found that methyl methacrylate reacted with allylic alcohol in the presence of 5% (in mole) of sodium, to give a mixture of four products, whose 20% of the desired Michael product. Transesterification was the main process.



R = allyl 55% 20% 19% 6%

Table 2 : Preparation of 3-(n-alkenoxy)propanoic acids **3** via formation and hydrolysis of *tert*-butyl esters **4**.

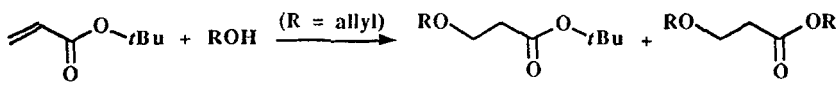


1 **4** **3**

alkenols **1**	reaction time (h)	% Yield **4**		reaction time (h)	% Yield [a] **3**	
1a $R_1 = R_2 = R_3 = H$, n = 1	(4)	95	**4a**	(24)	80	**3a**
1d $R_1 = R_2 = R_3 = H$, n = 2	(2.5)	94	**4d**	(10)	89	**3d**
1e $R_1 = R_2 = R_3 = H$, n = 3	(91)	45	**4e**	(14)	78	**3e**
1f $R_1 = R_3 = Me$, $R_2 = H$, n = 1	(15)	74	**4f**	(6)	0	**3f**
1g $R_1 = R_3 = H$, $R_2 = Me$, n = 2	(2.5)	91	**4g**	(5.5)	72	**3g**

[a] Refers to purified material.

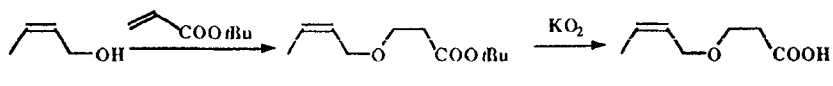
In same conditions, we found that *tert*-butyl acrylate reacted with allylic alcohol to give only Michael addition products in 90% yield. Chemioselectivity of the reaction was improved by substitution of the sodium cation by lithium or ammonium cations. With N-benzyltrimethylammonium hydroxide (Triton B), exclusive formation of the desired product was observed.



0.05 eq. Na	82	18
0.1 eq. nBuLi	98	2
0.1 eq. Triton B	100	0

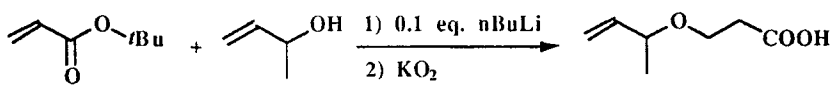
Cleavage of *tert*-butyl ester was then accomplished with trifluoroacetic acid in methylene chloride.[7] A non aqueous work-up allowed the isolation of 3-(n-alkenoxy)propanoic acids **3a-3e**. Our results are reported in Table 2.

Alkenoxy esters **4a-4e**, **4g** were obtained in moderate to high yields and cleavage of *tert*-butyl esters occured without problems. Intermediate isolation of esters **4** could be avoided, and preparation of acids **3** could be conducted in a one pot reaction, with similar overall yields. For acid **3f** degradation was the unique process and its unsuccessful preparation conducted us to search an other cleavage method. We found that this deprotection could be conducted using potassium superoxide in the presence of 18-crown-6 ether (70% yield).[8] In the same way, ester **4h** prepared by reaction of (Z)-2-buten-1-ol with *tert*-butyl acrylate (Triton B, 55% yield) was cleaved without isomerization of the carbon-carbon double bond (69% yield).



1h **4h** **3h**

Triton B was not always the best catalyst in the Michael reaction. In the case of secondary alcohol **1i**, lithium salt was more effective and subsequent cleavage with potassium superoxide allowed the obtention of the acid **3i** (45% Yield).



1i **3i**

In short, we have reported new possibilities for the preparation of 3-(n-alkenoxy)-propanoic acids employing a two step pathway. Successful Michael additions using *tert*-butyl acrylate and its subsequent cleavage was achieved. However, in some particular cases we cannot exclude that strategy employing acrylonitrile might be the best, notwithstanding the difficult basic nitrile function hydrolysis.[9]

EXPERIMENTAL SECTION

Infrared spectra were recorded on a Perkin-Elmer 682 spectrophotometer. ^1H NMR spectra were obtained in $CDCl_3$ as solvent and internal standard on

AC200 or AC250 Bruker instruments. Mass spectral data were recorded with a Nermag R10-10 mass spectrometer at a ionizing voltage of 70 eV (EIMS) and chemical ionization (CIMS) was accomplished with ammonia. Most of starting materials are commercial. (Z)-3-buten-1-ol **1h** was prepared from butyn-3-ol by cis-hydrogenation in the presence of Lindlar catalyst (Z/E > 99/1).[10]

Preparation of 3-(n-alkenoxy)propionitriles 2a-2e :

General Procedure. In a dried flask containing Triton B (40% sol. in MeOH, 1.2 ml) was added dropwise alcohol **1a - 1e** (0.21 mol) followed after 15 min by acrylonitrile (0.25 mol). The mixture was stirred at room temperature in the dark. After completion of the reaction (checked by GC) excess of acrylonitrile was removed under vacuum. The residue was acidified with 10 ml of acetic acid and the product purified by distillation under reduced pressure.

3-(2-Propenoxy)propionitrile 2a : IR (neat, cm^{-1}) : ν 3080, 2870, 2250 (CN), 1650, 1420, 1350, 1100, 990, 925 ; ^1H NMR (200 MHz) δ : 2.63 (t, ^3J = 6.4 Hz, 2H, $OCH_2C\underline{H}_2CN$) ; 3.68 (t, ^3J = 6.4 Hz, 2H, $OC\underline{H}_2CH_2CN$) ; 4.06 (bd, ^3J = 5.5 Hz, 2H, $=CHC\underline{H}_2O$) ; 5.25 (bd, ^3J = 11.4 Hz, 1H) and 5.33 (bd, ^3J = 16.3 Hz, 1H) ($\underline{H}_2C=CH$); 5.93 (m, 1H, $H_2C=C\underline{H}CH_2O$) ; CIMS *m/z* (rel. intensity) : 129 ($M+NH_4^+$, 100) , 128 (14) ; EIMS *m/z* (rel. intensity) : 111 (M^+, 2), 82 (10), 58 (10), 57 (49), 55 (38), 54 (72), 41 (100), 40 (12), 39 (49) ; colourless liquid ; bp / 19 mmHg = 96°C.

3-(2-Methyl-2-propenoxy)propionitrile 2b : IR (neat, cm^{-1}) : ν 3080, 2940, 2255 (CN), 1660, 1110, 900 ; ^1H NMR (250 MHz) δ : 1.73 (s, 3H, $=CCH_3$) ; 2.60 (t, ^3J = 6.2 Hz, 2H, $OCH_2C\underline{H}_2CN$) ; 3.60 (t, ^3J = 6.2 Hz, 2H, $OC\underline{H}_2CH_2CN$) ; 3.92 (s, 2H, $=CCH_2O$) ; 4.92 (d, ^3J = 1.1 Hz, 1H) and 4.97 (d, ^3J = 1.1 Hz, 1H) ($C=CH_2$) ; EIMS *m/z* (rel. intensity) : 125 (M^+, 1), 110 (29), 94 (19), 71 (17), 57 (73), 55 (100), 54 (73), 53 (20), 43 (30), 41 (44), 39 (63) ; colourless liquid ; bp / 8 mmHg = 91 - 93°C ; R_f (ether) = 0.65.

(E)-3-(2-Butenoxy)propionitrile 2c : IR (neat, cm^{-1}) : ν 3030, 2950, 2930, 2880, 2260 (CN), 1680, 1110, 975 ; ^1H NMR (250 MHz) δ : 1.73 (d, ^3J = 5.6 Hz, 3H, $=CHC\underline{H}_3$) ; 2.60 (t, ^3J = 6.6 Hz, 2H, $OCH_2C\underline{H}_2CN$) ; 3.63 (t, ^3J = 6.6 Hz, 2H, $OC\underline{H}_2CH_2CN$) ; 3.97 (d, ^3J = 6.6 Hz, 2H, $=CH\text{-}C\underline{H}_2O$) ; 5.57 (td, ^3J = 6.6 and 15.7 Hz, 1H, $HC=C\underline{H}CH_2O$) ; 5.75 (qd, ^3J = 5.6 and 15.7 Hz, 1H, $=C\underline{H}\text{-}CH_3$) ; EIMS *m/z* (rel. intensity) : 125 (M^+, 1), 110 (45), 94 (20), 71 (15), 69 (13), 57 (53) ; 55 (100), 54 (59), 53 (14), 43 (15), 41 (23), 39 (34) ; colourless liquid ; bp / 8 mmHg = 96 - 99°C ; R_f (ether) = 0.63.

3-(3-Butenoxy)propionitrile 2d : IR (neat, cm^{-1}) : ν 3080, 2880, 2250 (CN), 1645, 1420, 1365, 1115, 1000, 920 ; ^1H NMR (200 MHz) δ : 2.37 (q, ^3J = 6.7 Hz, 2H, $=CHC\underline{H}_2CH_2O$) ; 2.61 (t, ^3J = 6.3 Hz, 2H, $OCH_2C\underline{H}_2CN$) ; 3.56 (t, ^3J = 6.7 Hz, 2H, $=CHCH_2C\underline{H}_2O$) ; 3.67 (t, ^3J = 6.3 Hz, 2H, $OC\underline{H}_2CH_2CN$) ; 5.07 (bd, ^3J = 9.9 Hz,1H) and 5.13 (bd, ^3J = 12.0 Hz, 1H) ($\underline{H}_2C=CH$) ; 5.82 (m, 1H, $=C\underline{H}CH_2$) ; EIMS *m/z* (rel. intensity) : 125 (M^+, 0.1), 84 (31), 55 (15), 54 (100), 39 (10) ; colourless liquid ; bp / 18 mmHg = 105 - 107°C ; R_f (ether) = 0.65.

3-(4-Pentenoxy)propionitrile 2e : IR (neat, cm^{-1}) : ν 3080, 2940, 2880, 2250 (CN), 1645, 1420, 1370, 1120, 915 ; ^1H NMR (200 MHz) δ : 1.70 (bqt, ^3J = 7.2 Hz, 2H, $=CHCH_2C\underline{H}_2CH_2O$) ; 2.14 (bq, ^3J = 7.2 Hz, 2H, $=CHC\underline{H}_2CH_2CH_2O$) ; 2.61 (t, ^3J = 6.3 Hz, 2H, $OCH_2C\underline{H}_2CN$) ; 3.50 (t, ^3J = 6.5 Hz, 2H, $=CHCH_2CH_2C\underline{H}_2O$) ; 3.66 (t, ^3J = 6.3 Hz, 2H, $OC\underline{H}_2CH_2CN$) ; 4.98 (d, ^3J = 8.9 Hz, 1H) and 5.05 (d, ^3J = 14.9 Hz, 1H) ($\underline{H}_2C=CH$) ; 5.82 (m, 1H, $H_2C=C\underline{H}CH_2$) ; CIMS *m/z* (rel. intensity) : 157 ($M+NH_4^+$, 100) ; colourless liquid ; bp / 0.65 mmHg = 58 - 60°C ; R_f (ether) = 0.64.

Preparation of 3-(n-alkenoxy)propanoic acids 3a-3e by hydrolysis of nitriles 2a - 2e : General Procedure.

To a flask at 15°C containing water (70 ml) was added in 10 min under vigourous stirring sodium peroxide (0.18 mol, 1.3 eq), followed by 30% hydrogen peroxide (0.18 mol, 1.3 eq.), 3-(n-alkenoxy)propionitrile **2a - 2e** (0.14 mol), water (50 ml) and methanol (30 ml). After completion of the reaction (followed by TLC), excess of reagents was destroyed by addition of 5% Pd/C (600 mg). After acidification with 6N HCl (70 ml), methanol was removed under vacuum. The aqueous layer was extracted in continuous with ether (24h). After concentration, the organic layer provided a yellow oil which was partially diluted in methylene choride and filtered. The filtrate was dried ($MgSO_4$) and concentrated. The product was purified by distillation under reduced pressure.

3-(2-Propenoxy)propanoic acid 3a : Already obtained.[3b]

3-(2-Methyl-2-propenoxy)propanoic acid 3b : IR (neat, cm^{-1}) : ν 3600 - 2400 (OH), 3080, 2980, 2920, 1720 (CO), 1660, 1190, 1110, 900 ; ^1H NMR (250 MHz) δ : 1.73 (bs, 3H, $=CCH_3$) ; 2.66 (t, ^3J = 6.4 Hz, 2H, $OCH_2C\underline{H}_2CO_2H$) ; 3.69 (t, ^3J = 6.4 Hz, 2H, $OC\underline{H}_2CH_2CO_2H$) ; 3.91 (bs, 2H, $=CCH_2O$) ; 4.91 (bs, 1H) and 4.96 (bs, 1H) ($H_2C=$) ; 9.00 - 10.10 (m, 1H, CO_2H) ; CIMS *m/z* (rel. intensity) : 162 ($M+NH_4^+$, 100), 145 ($M+H^+$, 23) ; EIMS *m/z* (rel. intensity) :

144 (M^+, 8), 73 (97), 72 (100), 71 (97), 57 (85), 56 (27), 55 (67), 54 (13), 53 (13), 45 (25), 43 (33), 42 (12), 41 (25), 39 (39) ; colourless liquid ; bp / 0.25 mmHg = 79°C ; R_f (ether) = 0.50.

(E)-3-(2-Butenoxy)propanoic acid 3c : IR (neat, cm^{-1}) : ν 3700 - 2400 (OH), 3020, 2920, 2870, 1720 (CO), 1675, 1440, 1190, 1100, 1050, 955 ; ^1H NMR (250 MHz) δ : 1.73 (d, ^3J = 6.1 Hz, 2H, =CHC$\underline{H}_3$) ; 2.67 (t, ^3J = 6.2 Hz, 2H, $CH_2C\underline{H}_2CO_2H$) ; 3.70 (t, ^3J = 6.2 Hz, 2H, $OC\underline{H}_2CH_2CO_2H$) ; 3.94 (d, ^3J = 6.4 Hz, 2H, =CHC$\underline{H}_2$O) ; 5.56 (t, 1H, ^3J = 6.4 and 15.3 Hz, =C$\underline{H}$CH$_2$O) ; 5.72 (qd, ^3J = 6.3 and 15.3 Hz, 1H, =C$\underline{H}$CH$_3$) ; 9.60 - 10.10 (m, 1H, CO_2H) ; EIMS *m/z* (rel. intensity) : 144 (M^+, 2), 73 (63), 72 (25), 71 (100), 57 (33), 55 (59), 53 (12), 45 (14), 43 (19), 41 (14) ; colourless liquid ; bp / 0.7 mmHg = 112 - 115°C ; R_f (ether) = 0.58.

3-(3-Butenoxy)propanoic acid 3d : IR (neat, cm^{-1}) : ν 3600 - 2400 (OH), 3080, 2980, 2920, 2880, 1720 (CO), 1430, 1190, 1100, 915 ; ^1H NMR (250 MHz) δ : 2.35 (bq, ^3J = 6.6 Hz, 2H, =CHC$\underline{H}_2$CH$_2$O) ; 2.65 (t, ^3J = 5.8 Hz, 2H, $OCH_2C\underline{H}_2CO_2H$) ; 3.54 (t, ^3J = 6.6 Hz, 2H, =CHCH$_2$C$\underline{H}_2$O) ; 3.73 (t, ^3J = 5.8 Hz, 2H, $OC\underline{H}_2CH_2CO_2H$) ; 5.05 (bd, ^3J = 9.2 Hz, 1H) and 5.10 (bd, ^3J = 13.9 Hz, 1H) ($\underline{H}_2$C=CH) ; 5.82 (m, 1H, H$_2$C=C$\underline{H}$CH$_2$) ; 8.60 - 9.20 (m, 1H, CO_2H) ; CIMS *m/z* (rel. intensity) : 162 ($M+NH_4^+$, 100), 145 ($M+H^+$, 23) ; EIMS *m/z* (rel. intensity) : 103 (30), 73 (100), 55 (19), 45 (10) ; colourless liquid ; bp / 0.7 mmHg = 87 - 89°C ; R_f (ether) = 0.52.

3-(4-Pentenoxy)propanoic acid 3e : IR (neat, cm^{-1}) : ν 3600 - 2400 (OH), 3080, 2940, 2880, 1720 (CO), 1645, 1435, 1170, 1115, 910 ; ^1H NMR (250 MHz) δ : 1.68 (bqt, ^3J = 6.6 Hz, 2H, =CHCH$_2$C$\underline{H}_2$CH$_2$O) ; 2.10 (bq, ^3J = 7.1 Hz, 2H, =CHC$\underline{H}_2$CH$_2$) ; 2.64 (t, ^3J = 6.3 Hz, 2H, $OCH_2C\underline{H}_2CO_2H$) ; 3.48 (t, ^3J = 6.6 Hz, 2H, =CHCH$_2$CH$_2$C$\underline{H}_2$O) ; 3.71 (t, ^3J = 6.3 Hz, 2H, $OC\underline{H}_2CH_2CO_2H$) ; 4.97 (bd, ^3J = 9.6 Hz, 1H) and 5.02 (bd, ^3J = 17.9 Hz, 1H) ($\underline{H}_2$C=CH) ; 5.81 (m, 1H, H$_2$C=C$\underline{H}$CH$_2$) ; 10.50 - 11.10 (m, 1H, CO_2H) ; CIMS *m/z* (rel. intensity) : 176 ($M+NH_4^+$, 100), 159 ($M+H^+$, 63), 158 (M^+, 13) ; EIMS *m/z* (rel. intensity) : 73 (95), 69 (13), 68 (100), 67 (69), 55 (20), 53 (13), 45 (21), 43 (12), 42 (11), 41 (38), 39 (22) ; colourless liquid ; bp / 3 mmHg = 120°C ; R_f (ether) = 0.54.

Preparation of *tert*-butyl 3-(n-alkenoxy)propanoates 4a, 4d - 4g : General Procedure.

To a dried flask was placed Triton B (40% in methanol, 1.2 ml) and the solvent was removed under reduced pressure. Alcohol **1a - 1g** (0.07 mol) was

added, followed after 15 min by *tert*-butyl acrylate (0.06 mol). After completion of the reaction made at 50°C (cheked by GC), the resulting solution was filtered over a mixture Celite-silica gel and concentrated under vacuum. The product was purified by distillation under reduced pressure or was used without purification for the next step.

tert-Butyl 3-(2-propenoxy)propanoate ***4a*** : IR (neat, cm^{-1}) : *v* 3080, 2980 (F, tBu), 2940, 2870, 1740 (CO), 1370, 1260, 1160, 1100, 1070, 1010, 920, 850, 800 ; ^1H NMR (200 MHz) δ : 1.45 (bs, 9H, O-C(CH_3)$_3$) ; 2.52 (t, ^3J = 6.6 Hz, 2H, $OCH_2C\underline{H}_2CO_2tBu$) ; 3.68 (t, ^3J = 6.6 Hz, 2H, $OC\underline{H}_2CH_2CO_2tBu$) ; 3.98 (bd, ^3J = 5.8 Hz, 2H, $=CHC\underline{H}_2O$) ; 5.18 (dd, ^3J = 10.6 Hz and 1.0 Hz, 1H) and 5.28 (dd, ^3J = 17.2 and 1.6 Hz, 1H) ($\underline{H}_2C=CHCH_2O$) ; 5.90 (m, 1H, $H_2C=C\underline{H}CH_2O$) ; CIMS *m/z* (rel. intensity) : 204 ($M+NH_4^+$, 14), 187 ($M+H^+$, 11), 148 (100), 131 (11) ; EIMS *m/z* (rel. intensity) : 130 (18), 113 (22), 89 (19), 73 (22), 71 (33), 58 (21), 57 (tBu^+, 100), 56 (14), 55 (15), 43 (12), 41 (79), 39 (18) ; colourless liquid ; bp / 1 mmHg = 63°C.

tert-Butyl 3-(3-butenoxy)propanoate ***4d*** : ^1H NMR (250 MHz) δ : 1.46 (bs, 9H, O-C(CH_3)$_3$) ; 2.33 (bq, ^3J = 6.5 Hz, 2H, $=CHC\underline{H}_2CH_2O$) ; 2.50 (t, ^3J = 6.5 Hz, 2H, $OCH_2C\underline{H}_2CO_2tBu$) ; 3.50 (t, ^3J = 6.5 Hz, 2H, $=CCH_2C\underline{H}_2O$) ; 3.69 (t, ^3J = 6.5 Hz, 2H, $OC\underline{H}_2CH_2CO_2tBu$) ; 5.03 (bd, ^3J = 9.5 Hz, 1H) and 5.09 (bd, ^3J = 17.2 Hz, 1H) ($\underline{H}_2C=CH$) ; 5.82 (m, 1H, $H_2C=C\underline{H}CH_2$) ; yellowish liquid.

tert-Butyl 3-(4-pentenoxy)propanoate ***4e*** : IR (neat, cm^{-1}) : *v* 3080, 2980 (F, tBu), 2940, 2870, 1735 (CO), 1645, 1370, 1255, 1160, 1115, 910 ; ^1H NMR (200 MHz) δ : 1.43 (bs, 9H, O-C(CH_3)$_3$) ; 1.63 (bqt, ^3J = 6.6 Hz, 2H, $=CHCH_2C\underline{H}_2CH_2O$) ; 2.09 (bd, ^3J = 6.6 Hz, 2H, $=CHC\underline{H}_2CH_2$) ; 2.46 (t, ^3J = 6.3 Hz, 2H, $OCH_2C\underline{H}_2CO_2tBu$) ; 3.43 (t, ^3J = 6.3 Hz, 2H, $OC\underline{H}_2CH_2CO_2tBu$) ; 3.64 (bd, ^3J = 6.0 Hz, 2H, $=CHCH_2CH_2C\underline{H}_2O$) ; 4.93 (bd, ^3J = 9.6 Hz, 1H) and 5.00 (bd, ^3J = 16.5 Hz, 1H) ($\underline{H}_2C=CH$) ; 5.79 (m, 1H, $H_2C=C\underline{H}CH_2$) ; EIMS *m/z* (rel. intensity) : 157 (M^+ -tBu, 1), 81 (14), 74 (30), 73 (37), 71 (18), 70 (31), 69 (100), 68 (98), 67 (28), 58 (46), 57 (tBu^+, 94), 56 (11), 55 (11), 41 (35), 39 (12) ; colourless liquid ; bp / 0.45 mmHg = 60 - 63°C.

tert-Butyl 3-(3-methyl-2-butenoxy)propanoate ***4f*** : IR (neat, cm^{-1}) : *v* 3010, 2980 (F, tBu), 2930, 2870, 1735 (CO), 1370, 1160, 850 ; ^1H NMR (250 MHz) δ : 1.47 (s, 9H, O-C(CH_3)$_3$) ; 1.68 (bs, 3H) and 1.75 (bs, 3H) (($C\underline{H}_3$)$_2$C=CH) ; 2.50 (t, ^3J = 6.3 Hz, 2H, $OCH_2C\underline{H}_2CO_2tBu$) ; 3.67 (t, ^3J = 6.3 Hz, 2H, $OC\underline{H}_2CH_2CO_2tBu$) ; 3.98 (bd, ^3J = 6.8 Hz, 2H, $=CHC\underline{H}_2O$) ; 5.35 (bt, ^3J = 6.8

Hz, 1H, $(H_3C)_2C=C\underline{H}CH_2O$) ; CIMS *m/z* (rel. intensity) : 176 (100) ; EIMS *m/z* (rel. intensity) : 158 (19), 157 (M^+ -tBu, 33), 143 (13), 85 (98), 73 (13), 71 (25), 69 (100), 68 (22), 67 (11), 57 (tBu^+, 56), 55 (13), 41 (52), 39 (14) ; yellowish liquid.

tert-Butyl 3-(3-methyl-3-butenoxy)propanoate 4g : IR (neat, cm^{-1}) : *v* 3080, 2980 (F, tBu), 2940, 2870, 1735 (CO), 1650, 1370, 1160, 1115, 885, 845 ; ^1H NMR (200 MHz) δ : 1.46 (s, 9H, O-C(CH_3)$_3$) ; 1.75 (s, 3H, =C($C\underline{H}_3$)) ; 2.29 (bt, ^3J = 6.9 Hz, 2H, =$CC\underline{H}_2CH_2O$) ; 2.49 (t, ^3J = 6.5 Hz, 2H, $OCH_2C\underline{H}_2CO_2tBu$) ; 3.56 (t, ^3J = 6.9 Hz, 2H, =$CCH_2C\underline{H}_2O$) ; 3.68 (t, ^3J = 6.5 Hz, 2H, $OC\underline{H}_2CH_2CO_2tBu$) ; 4.77 (bd, ^2J = 8.9 Hz, 2H, $\underline{H}_2C=C(CH_3)CH_2$) ; CIMS *m/z* (rel. intensity) : 232 ($M+NH_4^+$, 23), 176 (100) ; EIMS *m/z* (rel. intensity) : 103 (99), 97 (16), 73 (100), 70 (22), 69 (57), 68 (48), 57 (tBu^+, 81), 41 (64) ; colourless liquid ; R_f (ether) = 0.73.

tert-Butyl (Z)-3-(2-Butenoxy)propanoate 4h : IR ($CDCl_3$, cm^{-1}) : *v* 3020, 2980 (F, tBu), 2920, 1720 (CO) ; ^1H NMR (200 MHz) δ : 1.45 (s, 9H, O-C(CH_3)$_3$) ; 1.65 (bd, ^3J = 6.2 Hz, 3H, $\underline{H}_3CCH$=) ; 2.50 (t, ^3J = 6.6 Hz, 2H, $OCH_2C\underline{H}_2CO_2tBu$) ; 3.66 (t, ^3J = 6.6 Hz, 2H, $OC\underline{H}_2CH_2CO_2tBu$) ; 4.04 (bd, ^2J = 6.6 Hz, 2H, =$CHC\underline{H}_2O$) ; 5.60 (m, 2H, $H_3C\underline{CH}=\underline{CH}CH_2O$) ; yellowish liquid.

Preparation of *tert*-butyl 3-(1-methyl-2-propenoxy)propanoate 4i.

To a dried flask under argon containing 3-buten-2-ol **1i** (0.022 mol) was added at 0°C nBuLi (0.1 eq., 1.25 ml sol. 1.6M in hexane) followed after 10 min by *tert*-butyl acrylate (0.02 mol). The mixture was left 20h at room temperature. Acidification with formic acid (0.2 ml), and concentration under reduced pressure gave a suspension which was partially diluted in dichloromethane and then filtered over a mixture Celite-silica gel. Concentration under vacuum gave the crude *tert*-butyl ester **4i** (78% yield ; purety>95%).

IR (neat, cm^{-1}) : *v* 3080, 2980, 2940, 2870, 1735 (CO), 1645, 1370, 1160, 1100, 990, 920, 845 ; ^1H NMR (200 MHz) δ : 1.23 (d, ^3J = 6.6 Hz, 3H, $C\underline{H}_3CH$-O) ; 1.46 (s, 9H, O-C(CH_3)$_3$) ; 2.48 (t, ^3J = 6.6 Hz, 2H, $OCH_2C\underline{H}_2CO_2tBu$) ; 3.63 (m, 2H, $OC\underline{H}_2CH_2CO_2tBu$) ; 3.85 (m, 1H, =$CHC\underline{H}(CH_3)O$) ; 5.13 (d, ^3J = 8.7 Hz, 1H) and 5.19 (d, ^3J = 15.0 Hz, 1H) ($\underline{H}_2C=CHCH$) ; 5.74 (m, 1H, $H_2C=C\underline{H}CH(CH_3)$) ; CIMS *m/z* (rel. intensity) : 218 ($M+NH_4^+$, 2), 162 (100), 145 (33) ; EIMS *m/z* (rel. intensity) : 144 (11), 129 (18), 89 (15), 73 (39), 72 (11), 71 (19), 59 (21), 57 (tBu^+, 100), 56 (19), 55 (91), 43 (35), 41 (45), 39 (17) ; yellow liquid ; R_f (ether) = 0.70.

Preparation of 3-(n-alkenoxy)propanoic acids 3a, 3d - 3g by CF_3COOH hydrolysis of *tert*-butyl esters 4a, 4d - 4g: General Procedure.

To a dried flask containing *tert*-butyl ester 3 (0.05 mol) was added dichloromethane (8 ml) and trifluoroacetic acid (0.15 mol). The mixture was stirred at reflux. After completion of the reaction (checked by GC) and concentration, the acid was purified by distillation under vacuum.

3-(3-Methyl-3-butenoxy)propanoic acid 3g : IR (neat, cm^{-1}) : *v* 3700 - 2400 (OH), 3080, 2980, 2940, 2880, 1720 (CO), 1650, 1370, 1215, 1165, 1115, 890 ; ^1H NMR (200 MHz) δ : 1.75 (bs, 3H, $=C(CH_3)$) ; 2.31 (t, ^3J = 6.9 Hz, 2H, $=C(CH_3)C\underline{H_2}CH_2O$) ; 2.65 (t, ^3J = 6.3 Hz, 2H, $OCH_2C\underline{H_2}CO_2H$) ; 3.60 (t, ^3J = 6.9 Hz, 2H, $=C(CH_3)CH_2C\underline{H_2}O$) ; 3.74 (t, ^3J = 6.3 Hz, 2H, $OC\underline{H_2}CH_2CO_2H$) ; 4.76 (bd, ^2J = 11.1 Hz, 2H, $\underline{H_2}C=C(CH_3)CH_2$) ; 10.10 - 10.80 (m, 1H, CO_2H) ; CIMS *m/z* (rel. intensity) : 176 ($M+NH_4^+$, 100), 159 ($M+H^+$, 11) ; EIMS *m/z* (rel. intensity) : 103 (21), 73 (100), 70 (11), 68 (34), 55 (11), 41 (18), 39 (11) ; colourless liquid ; bp / 0.05 mmHg = 70°C.

Preparation of 3-(n-alkenoxy)propanoic acids 3a, 3d - 3g by KO_2 hydrolysis of *tert*-butyl esters 4a, 4d - 4g: General Procedure.

tert-Butyl esters were cleaved with KO_2 according to [8]. We worked with toluene instead of benzene and the reaction have to be managed carefully : if potassium superoxide was more concentrated than described, it could be explosive ! Starting materials must be introduced under argon at 0°C. Afterwards, the reaction could be conducted under normal atmosphere at room temperature. Acidification was made at -10°C with cold 6N HCl.

3-(3-Methyl-2-butenoxy)propanoic acid 3f : IR (neat, cm^{-1}) : *v* 3600 - 2400 (OH), 3020, 2970, 2920, 2870, 1715 (CO), 1675, 1440, 1375, 1185, 1090, 1075 ; ^1H NMR (200 MHz) δ : 1.70, 1.77 (2xbs, 2x3H, $(H_3C)_2C=$) ; 2.66 (t, ^3J = 6.3 Hz, 3H, $OCH_2C\underline{H_2}CO_2H$) ; 3.72 (t, ^3J = 6.3 Hz, 2H, $OC\underline{H_2}CH_2CO_2H$) ; 4.02 (bd, ^3J = 7.3 Hz, 2H, $(=CHC\underline{H_2}O)$; 5.35 (m, 1H, $(=C\underline{H}CH_2O)$; 10.25 - 10.50 (m, 1H, CO_2H) ; CIMS *m/z* (rel. intensity) : 177 (36), 176 ($M+NH_4^+$, 100), 159 ($M+H^+$, 24), 157 (24), 109 (36), 108 (55) ; EIMS *m/z* (rel. intensity) : 158 (M^+, 2), 143 (17), 85 (100), 84 (14), 73 (34), 71 (94), 69 (43), 68 (92), 67 (52), 55 (18), 53 (17), 45 (18), 43 (26), 42 (15), 41 (71), 39 (29) ; colourless liquid ; bp / 0.2 mmHg = 90°C.

(Z)-3-(2-Butenoxy)propanoic acid ***3h*** : IR (neat, cm^{-1}) : ν 3700 - 2400 (OH), 3010, 2980, 2930, 2870, 1715 (CO), 1640, 1365, 1220, 1160, 1090, 915, 730 ; ^1H NMR (200 MHz) δ : 1.68 (bd, ^3J = 6.2 Hz, 3H, =CHC$\underline{H}_3$) ; 2.66 (t, ^3J = 5.9 Hz, 2H, $OCH_2C\underline{H}_2CO_2H$) ; 3.73 (t, ^3J = 5.9 Hz, 2H, $OC\underline{H}_2CH_2CO_2H$) ; 4.10 (bd, 2H, $OC\underline{H}_2CH$=) ; 5.65 (m, 2H, $OCH_2C\underline{H}$=C$\underline{H}$Me) ; CIMS *m/z* (rel. intensity) : 163 (16), 162 ($M+NH_4^+$, 100), 145 ($M+H^+$, 13) ; EIMS *m/z* (rel. intensity) : 144 (M^+, 18), 143 (12), 89 (12), 73 (58), 72 (23), 71 (100), 59 (26), 57 (88), 56 (16), 55 (72), 41 (24), 39 (18) ; colourless liquid ; bp / 0.35 mmHg = 150°C.

3-(1-Methyl-2-propenoxy)propanoic acid ***3i*** : IR (neat, cm^{-1}) : ν 3600 - 2400 (OH), 3080, 2980, 2940, 2880, 1720 (CO), 1425, 1195, 1100, 990, 925 ; ^1H NMR (200 MHz) δ : 1.27 (d, ^3J = 6.4 Hz, 3H, $\underline{H}_3$CCH-O) ; 2.64 (t, ^3J = 6.1 Hz, 2H, $OCH_2C\underline{H}_2CO_2H$) ; 3.69 (m, H, $OC\underline{H}_2CH_2CO_2H$) ; 3.89 (bqt, ^3J = 6.4 Hz, 1H, =CHC$\underline{H}$(Me)O) ; 5.16 (bd, ^3J = 4.2 Hz, 1H) and 5.22 (bd, ^3J = 11.1 Hz, 1H) ($\underline{H}_2$C=CH) ; 5.74 (m, 1H, H_2C=C$\underline{H}$CH(Me)O) ; 9.85 - 10.02 (m, 1H, CO_2H) ; CIMS *m/z* (rel. intensity) : 162 ($M+NH_4^+$, 74), 145 ($M+H^+$, 100) ; EIMS *m/z* (rel. intensity) : 129 (11), 73 (100), 72 (54), 71 (77), 57(41), 56 (25), 55 (66), 45 (27), 44 (14), 43 (68), 40 (20) ; colourless liquid ; R_f (ether) = 0.53.

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