Lewis Acid Induced Additions to Unsaturated Fatty Compounds*

*By Ursula Biermann and Jürgen O. Metzger***

Fachbereich Chemie der Universität Oldenburg, Germany

Unsaturated fatty compounds such as oleic acid, which are of interest as renewable raw materials, can be functionalized at the C,C-double bond by Lewis acid induced addition reactions. The products are branched and highly functionalized fatty compounds which may have interesting properties. $SnCl_4$-induced additions of nitriles to methyl oleate and ethyl 10-undecenoate give the corresponding esters of the N-acylamino fatty acids. Alkylaluminium halide induced ene additions of formaldehyde to unsaturated fatty compounds yield primary homoallylic alcohols. β,γ-Unsaturated ketones are obtained in ethylaluminium dichloride induced Friedel-Crafts acylations of unsaturated fatty compounds with acyl chlorides and cyclic anhydrides.

Lewis-Säure induzierte Additionen an ungesättigte Fettstoffe

Ungesättigte Fettstoffe wie Ölsäure, die als nachwachsende Rohstoffe von großem Interesse sind, lassen sich an der C,C-Doppelbindung durch Lewis-Säure induzierte Additionsreaktionen funktionalisieren. Als Produkte sind verzweigte und hoch funktionalisierte Fettstoffe mit möglicherweise interessanten Eigenschaften zu erwarten. Die $SnCl_4$-induzierte Addition von Nitrilen an Ölsäuremethylester und 10-Undecensäureethylester ergibt die entsprechenden N-Acylaminofettsäureester. Mittels der Alkylaluminiumhalogenid induzierten En-Addition von Formaldehyd an ungesättigte Fettstoffe werden primäre Homoallylalkohole erhalten. Die Synthese der entsprechenden β,γ-ungesättigten Ketone ist durch Ethylaluminiumdichlorid induzierte Friedel-Crafts Acylierungen ungesättigter Fettstoffe mit Acylchloriden und cyclischen Anhydriden möglich.

Unsaturated fatty compounds such as 10-undecenoic acid, oleic acid, petroselinic acid and erucic acid are of interest as renewable raw materials[1]. These compounds can be functionalized at the C,C-double bond by electrophilic addition reactions to give products with possibly interesting and new properties. We are presenting our results on some Lewis acid induced addition reactions to 10-undecenoic acid, oleic acid and to the respective esters and alcohols. Up to now we studied the $SnCl_4$-induced Ritter-reaction[2], the alkylaluminium halide induced ene reaction with formaldehyde[3, 4] and the alkylaluminium halide induced Friedel-Crafts acylation[5, 6].

$SnCl_4$-induced Ritter-reaction

Reactions of alkenes with nitriles in the presence of concentrated sulfuric acid give after hydrolysis N-alkylamides. These reactions are called Ritter-reactions[7]. *Roe* and *Swern*[8] examined the addition of some nitriles for example acetonitrile to oleic acid in 95 % sulfuric acid solution. The corresponding N-acylaminostearic acids were obtained in yields of up to 99 %. In sulfuric acid, however, considerable isomerization occurred. The products showed a broad melting range. It is remarkable that the respective addition product of acrylonitrile was obtained as an oil and could not be crystallized.

We observed the addition of nitriles to unsaturated fatty compounds induced by the Lewis acid tin tetrachloride.

The reaction of methyl oleate and acrylonitrile (Fig. 1) in the presence of stoichiometric amounts of $SnCl_4$ and water was after a reaction time of 24 h at a temperature of 50 °C nearly quantitative. The crystalline product, methyl(N-acryl)-aminostearate was obtained in a yield of 96 % without problems. We observed only a moderate isomerization which was temperature dependent. The amide could be saponified to give the free amino compound. The addition of acetonitrile to methyl oleate was carried out as well to give (N-acetyl)-9(10)-aminostearate.

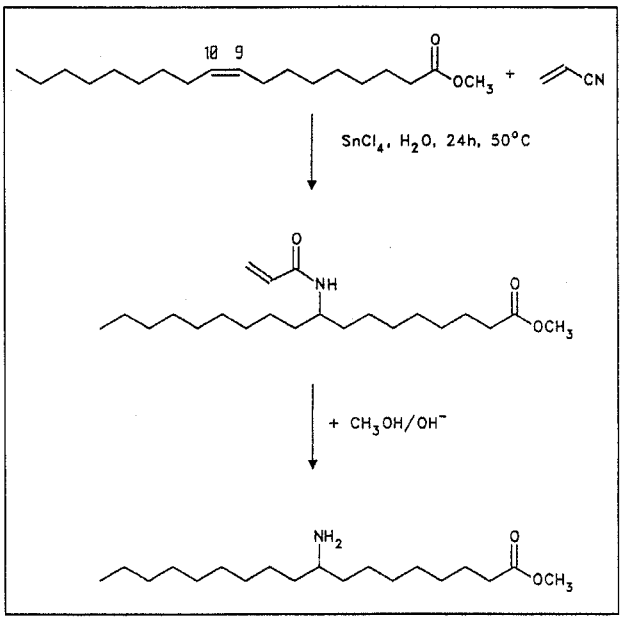

Fig. 1. $SnCl_4$-induced addition of acrylnitrile to methyl oleate

Alkylaluminium halide induced ene reactions with formaldehyde

The ene reaction of carbonyl compounds with alkenes is known to be a potentially valuable route to give homoallylic alcohols. *Snider et al.*[9] found that dimethylaluminium chloride (Me_2AlCl) is a useful promoter for ene reactions of aliphatic and aromatic aldehydes and leads to improved yields of ene adducts from formaldehyde. Me_2AlCl is a mild Lewis acid and a proton scavenger. Proton initiated rearrangements do not occur since the alcohol-Lewis acid complex formed in the ene reaction reacts rapidly to give methane and a non-acidic aluminium alkoxide. The introduction of functionality into the alkene i.e. COOH, OH, OCOR requires the stronger Lewis acid ethylaluminium dichloride ($EtAlCl_2$)[10].

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** Authors' address: Prof. Dr. *J. O. Metzger* and Dr. *Ursula Biermann*, Fachbereich Chemie der Universität Oldenburg, Postfach 2503, D-26111 Oldenburg, Germany.

We have been interested in the application of the alkylaluminium halide induced ene addition of formaldehyde to unsaturated fatty compounds.

The Me_2AlCl-induced reaction of 10-undecenoic acid and formaldehyde gave after a reaction time of 2 h the ene adduct in an isolated yield of 71 % (Fig. 2). The 12-hydroxy-dodec-9-enoic acid was obtained with high

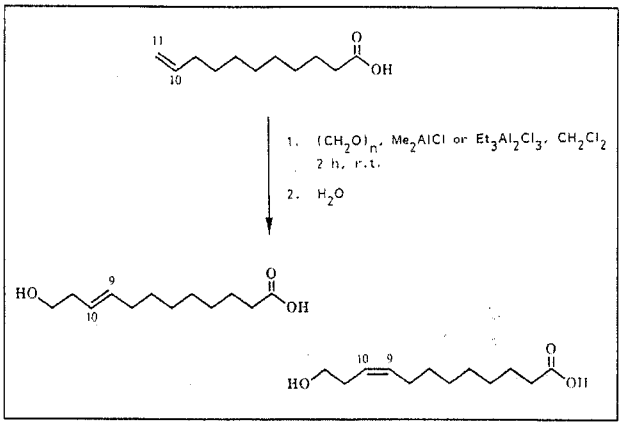

Fig. 2. Me_2AlCl-induced ene reaction of 10-undecenoic acid and formaldehyde

regioselectivity. The aldehyde was added exclusively to position C11 of the molecule chain. The ratio of the (*E*)/(*Z*)-isomers was 4:1. A two fold excess of Me_2AlCl was necessary because of the acid-base reaction of the Me_2AlCl and 10-undecenoic acid to give methane and aluminium salt. The reaction could also be induced by ethylaluminium sesquichloride ($Et_3Al_2Cl_3$).

The addition of formaldehyde to oleyl alcohol gave the expected unsaturated diol. The mixture of the regioisomers 9-(hydroxymethyl)octadec-10-en-1-ol and 10-(hydroxymethyl)octadec-8-en-1-ol was obtained with high stereoselectivity as (*E*)-adduct. The product was isolated in a yield of 65 % by column chromatography.

Whereas additions of formaldehyde to unsaturated acids and alcohols gave good yields of ene adducts in-

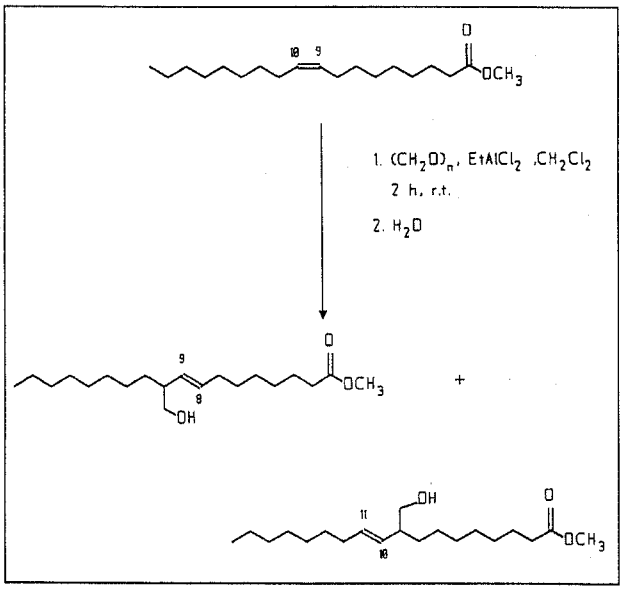

Fig. 3. $EtAlCl_2$-induced ene reaction of methyl oleate and formaldehyde

duced by Me_2AlCl and $Et_3Al_2Cl_3$ it was necessary to use $EtAlCl_2$, a stronger Lewis acid, for additions of formaldehyde to the respective esters. Thus, formaldehyde was added induced by $EtAlCl_2$ to methyl oleate in an isolated yield of 63 % (Fig. 3). The ratio of the 9- and 10-regioisomers was approximately 1:1. They were obtained as pure (*E*)-adducts. The alkylaluminium halide induced ene addition of formaldehyde to unsaturated fatty compounds is a suitable reaction to synthesize fatty compounds with the functionality of primary alcohols with retention of the double bond.

Alkylaluminium halide induced Friedel-Crafts acylation

The Friedel-Crafts acylation could be an interesting method to introduce functionality to an alkene[11-13]. This reaction induced by Lewis acids such as $AlCl_3$, $SnCl_4$ or $ZnCl_2$ often yields a mixture of products. The main products are β, γ-unsaturated ketones, α, β-unsaturated ketones and β-chloroketones[14]. *Snider* and *Jackson*[15] reported recently that $EtAlCl_2$-induced Friedel-Crafts acylations of cyclic and aliphatic alkenes with acid chlorides and acid anhydrides gave the corresponding β, γ-unsaturated ketones in yields of 53–73 %. As minor products β-chloroketones were identified. However, the reaction has not been applied to olefines with functional groups such as unsaturated acids or alcohols.

We applied the Friedel-Crafts acylation to oleic acid, 10-undecenoic acid, the respective esters and alcohols. The reactions with acyl chlorides and cyclic anhydrides should give linear and branched long chain fatty compounds with a β, γ-unsaturated keto functionality.

The reaction of 10-undecenoic acid with an acyl chloride and $EtAlCl_2$ (1:1:2) gave the β, γ-unsaturated ketocarboxylic acid with high regioselectivity (Fig. 4). The

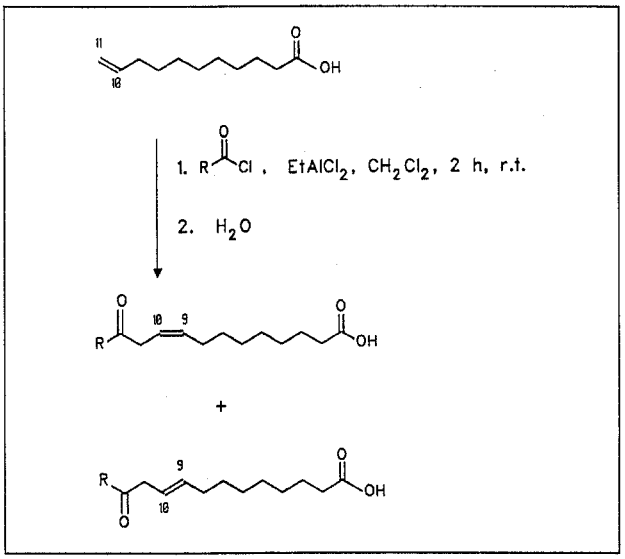

Fig. 4. $EtAlCl_2$-induced acylation of 10-undecenoic acid with acyl chlorides

product was obtained as a mixture of (*E*)/(*Z*)-isomers in a ratio of 3:1. The observed stereochemistry was in agreement with the results of *Snider* and *Jackson*[15]. The isolated yields of the acylation products obtained by column chromatography or by recrystallization were 50–67 %. Catalytic hydrogenation of the unsaturated

ketocarboxylic acids gave the saturated products in quantitative yields.

The acylation with acyl chlorides was also applied to oleic acid to give the corresponding β, γ-unsaturated branched ketocarboxylic acid.

The reaction of oleic acid with succinic anhydride and $EtAlCl_2$ (1:1:2) gave the expected β, γ-unsaturated ketodicarboxylic acid (Fig. 5). After a reaction time of 24 h at

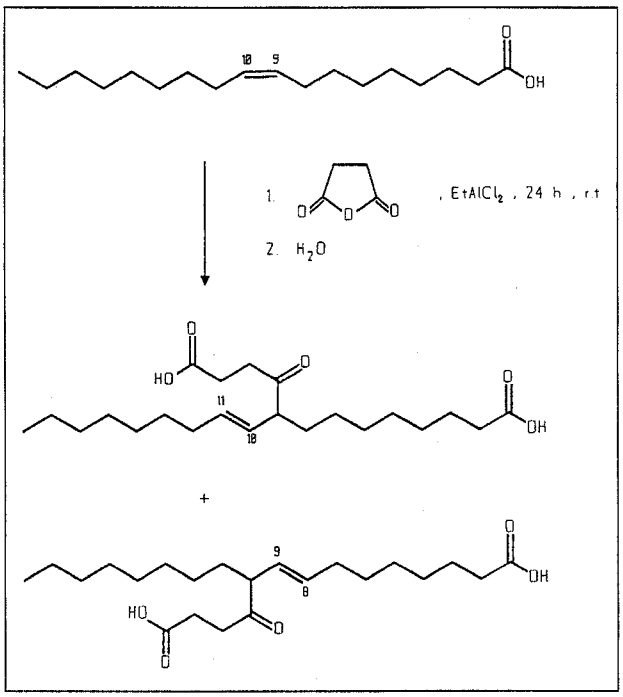

Fig. 5. $EtAlCl_2$-induced acylation of oleic acid with succinic anhydride

r.t. a mixture of (*E*)-9-(1-oxo-3-carboxypropyl)octadec-10-enoic acid and (*E*)-10-(1-oxo-3-carboxypropyl)octadec-8-enoic acid (ratio 1:1) was isolated in a yield of 45 %. By this reaction two functional groups, a carbonyl and a carboxyl group, are introduced to the molecule chain of the fatty acid. Hydrogenation of the acylation product gave the saturated ketodicarboxylic acid.

Acylations were also carried out with methyl oleate and methyl 10-undecenoate. The results with respect to

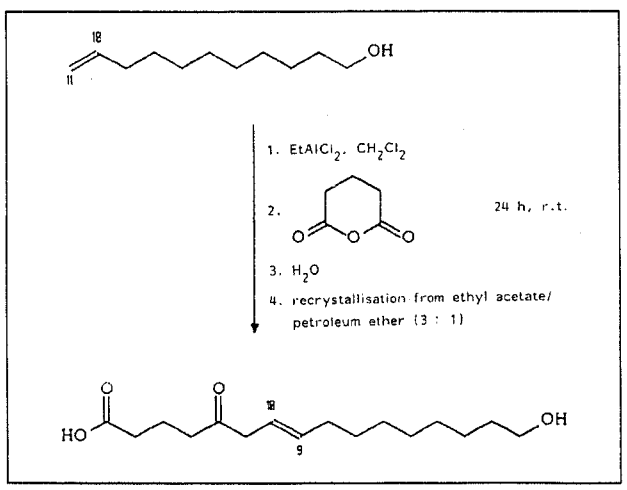

Fig. 6. $EtAlCl_2$-induced acylation of 10-undecenol with glutaric anhydrides

the regioselectivity and to the stereochemistry were identical to those obtained in the acylations of the free fatty acids.

In addition to unsaturated fatty acids and the respective methyl esters unsaturated fatty alcohols i. e. oleyl alcohol and 10-undecenol were acylated with acyl chlorides and cyclic anhydrides. As products the corresponding β, γ-unsaturated ketones with a ω-hydroxy functionality were obtained.

The $EtAlCl_2$-induced acylation of 10-undecenol with glutaric anhydride (Fig. 6) yielded after a reaction time of 24 h at r.t. and after recrystallization the pure (*E*)-adduct with 39 %. This reaction allows the synthesis of a long chain fatty compound with a carboxyl, a carbonyl and a primary alcohol functionality.

The $EtAlCl_2$-induced Friedel-Crafts acylation of unsaturated fatty compounds is a variable reaction, on the one hand by use of unsaturated fatty compounds such as acids, esters and alcohols and on the other hand by choice of different acylating agents.

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