

Sn-1(3) Monoacylglycerides and lipid absorption

The present invention relates generally to the field of lipids and in particular aims at improving lipid absorption, for example under conditions of lipid maldigestion or malabsorption. One embodiment of the present invention relates to a composition comprising sn-1(3) monoacylglycerols, wherein the sn-1 or sn-3 position is occupied by an acyl group such as a fatty acid and the sn-2 position remains unoccupied. The fatty acid may be one with anti-inflammatory properties.

- 10 The delivery of bioactive fatty acids under conditions of malabsorption such as in pancreatic insufficiency, bile salt deficiency, and short gut due to gut removal or mucosal disease is critical.

15 In these physiological conditions, the digestion pathways, involving degradation of dietary triglycerides by the pancreatic lipase and the formation of micellar macrostructures required for enteral uptake, are impaired.

The delivery of bioactive fatty acids having, e.g., anti-inflammatory properties is therefore critical in these conditions as this type of fatty acids could help to lower the inflammation response.

25 Based on previously published prior art (Freeman CP, et al., J Dairy Sci 1965;48:853-8; Innis SM, et al., Lipids 1994;29:541-5) it is currently understood that fatty acids located in the sn-2 position of a glyceride are more readily absorbed by the body than fatty acids in the sn-1(3) position.

One would hence assume that the provision of monoacylglycerols (MAGs) with a fatty acid in sn-2 position would be an ideal vehicle to provide fatty acids that can be easily absorbed.

However, sn-2 MAGs are known to isomerise, for example, with storage times and/or elevated temperatures to yield a mixture of sn-1(3) and sn-2 MAGs (Compton D.L., et al., 20007; Lyubachevskaya G and Boyle-Roden E., 2000). Hence, the use of Sn-2 MAGs is presently not considered an option to provide fatty acids for absorption more effectively than using fish oil.

For humans, there is presently no dietary solution available to deliver essential fatty acids effectively, in particular when mechanisms involved in lipid digestion and absorption are impaired. Hence, in hospital generally parenteral nutrition formulations are used.

In aged companion animals, such as old dogs or cats for example, there is equally no solution available as well.

However, it would be desired to have a food composition available that allows the efficient uptake of fatty acids even under conditions of lipid malabsorption.

Hence, it was the object of the present invention to provide the art with an optimal glyceride structure allowing a substantial uptake of fatty acids, for example fatty acids with anti-inflammatory properties, such as EPA, in particular in malabsorption conditions. This glyceride structure should be more efficient in delivering fatty acids than fish oil.

The inventors were surprised to see that - contrary to what is currently assumed in the art - they could achieve this object by the subject matter of the independent claim. The dependent claims define further embodiments of the present invention.

The inventors found that they could significantly improve fatty acid absorption by using a mixture of sn-2 and sn-1(3) MAGs.

Remarkably, the mixture of sn-2 and sn-1(3) MAGs was found to more effective in delivering fatty acids for absorption than pure sn-2 MAGs, contrary to what is presently believed in the art.

In addition, the mixture of sn-2 and sn-1(3) MAGs was found to provide fatty acids even under maldigestion or malabsorption conditions more effectively than fish oil under normal conditions.

Hence, the present invention is related to the use of sn-1(3) MAGs, possibly in combination with sn-2 MAGs (see Figure 1) to deliver bioactive fatty acids such as eicosapentaenoic acid (EPA), e.g., under lipid maldigestion or malabsorption conditions.

MAGs do not need to be digested prior to absorption and have intrinsic emulsifying properties allowing a good dispersion of oil droplets prior to absorption in the intestine.

The inventors tested their concept in a lipid maldigestion/malabsorption animal model. The malabsorption condition was obtained using Orlistat[®], a well known pancreatic and gastric lipases inhibitor. Animals were fed with long-chain polyunsaturated fatty acid (LC-PUFA) supplements containing mainly eicosapentaenoic (EPA) acid. Fish oil was used as a source of triacylglycerols and different EPA glycerides, for example those of Figure 1, were evaluated. At different time intervals the fatty acid profile of red blood cell and plasma lipids was assessed. At the end of the experiment, fatty acid profiles of different tissues were

determined. A statistical evaluation revealed that the use of Orlistat® decreases EPA incorporation in red blood cells. The level of, e.g., EPA incorporated in red blood cells in an animal receiving the sn-1(3)MAGs of the present invention was found to be significantly higher compared to the administration of fish oil with mixture of EPA in sn-1, sn-2 and sn-3 positions. This clearly demonstrates that, e.g., in conditions of lipid malabsorption, the incorporation of LC-PUFA provided as triacylglycerols is reduced. However, if LC-PUFA are provided as sn-1(3) MAGs the incorporation in tissue is not altered in conditions of lipid malabsorption/maldigestion.

Hence, one embodiment of the present invention is a composition comprising an sn-1(3) MAGs.

The acyl group may be a functional fatty acid.

Functional fatty acids are for the purpose of the present invention fatty acids that deliver a health benefit.

For example, the functional fatty acid may be a fatty acid with anti-inflammatory properties. Which fatty acids have anti-inflammatory properties is known to those of skill in the art.

For example, fatty acids having anti-inflammatory properties may be selected from the group consisting of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), α -linolenic acid (ALA), stearidonic acid (SA), γ -linolenic acid (GLA), dihomo- γ -linolenic acid (DGLA), docosapentanoic acid (DPA), sciadonic acid and juniperonic acid.

Sciadonic acid is 5Z,11Z,14Z-eicosatrienoic acid. Juniperonic acid is 5(Z),11(Z),14(Z),17(Z)-eicosatetraenoic acid.

Typical MAGs that may be employed in the framework of the present invention may be selected from the group consisting of sn-1(3)-monoeicosapentaenoylglycerol,

sn-1(3)-monodocosahexaenoylglycerol,

5 sn-1(3)-monooctadecatrienoylglycerol,

sn-1(3)-monooctadecatetraenoylglycerol,

sn-1(3)-monoeicosatrienoylglycerol,

sn-1(3)-monodocosapentaenoylglycerol,

sn-1(3)-monosciadonylglycerol,

10 sn-1(3)-monojuniperonylglycerol or combinations thereof.

For example, the inventors obtained very good results with sn-1(3) monoeicosapentaenoylglycerol as sn-1(3)-monoacylglycerol.

Here, even under maldigestion/malabsorption conditions the fatty acids were better absorbed than the fatty acids of fish oil under normal conditions (Figure 2).

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Of course, the composition may comprise a mixture of different MAGs with different fatty acids in the sn-1(3) position.

The fatty acids may be mixed in a way, for example, that a particular ratio between n-3 and n-6 fatty acids is used.

20 n-3 fatty acids include for example α -linolenic acid, stearidonic acid, eicosatrienoic acid, n-3 eicosatetraenoic acid, eicosapentaenoic acid, , clupanodonic acid, docosahexaenoic acid, n-3 tetracosapentaenoic acid, or n-3 tetracosahexaenoic acid.

25 n-6 fatty acids include for example linoleic acid, γ -linolenic acid, n-6 eicosadienoic acid, dihomo- γ -linolenic acid, arachidonic acid, n-6 docosadienoic acid, adrenic acid, n-6 docosapentaenoic acid or calendic acid.

The composition may contain a combination of different sn-1(3) monoacylglycerides; for example with a ratio of n-3 to n-6 fatty acids of about 5:1 to about 15:1; for example about 8:1 to about 10:1.

- 5 For example, composition of the present invention may be for use in the delivery of fatty acids having anti-inflammatory properties.

The composition of the present invention is in particular useful under conditions of lipid maldigestion or malabsorption.

- 10 Consequently, the composition of the present invention may be to be administered to subjects suffering from a lipid maldigestion or malabsorption condition.

- The composition is useful for subject suffering from any kind of lipid maldigestion or malabsorption condition. For example,
15 such a malabsorption condition may be due to pancreatic insufficiency, bile salt deficiency, a mucosal disorder and/or a short gut.

- For example, if the fatty acid comprised by the MAG derivative is a fatty acid having anti-inflammatory properties, the
20 composition in accordance with the present invention may be for use in the treatment or prevention of inflammatory disorders.

- The present invention also relates to the use of an sn-1(3) monoacylglycerol, wherein the acyl group is a fatty acid
25 having anti-inflammatory properties for the preparation of a composition to treat or prevent inflammatory disorders, in particular under lipid maldigestion and/or malabsorption conditions.

- The inflammatory disorder may be selected from the group consisting of acute inflammations such as sepsis, and chronic inflammations such as inflammatory bowel disease, Crohn's disease, ulcerative colitis, necrotizing enterocolitis, skin inflammation, such as UV or chemical-induced skin inflammation, eczema, reactive skin, psoriasis, vitiligo, acne, inflammatory bowel syndrome, liver inflammation, alcoholic cirrhosis, allergy, atopy, bone inflammation, rheumatoid arthritis, systemic lupus, dermatomyositis, thyroiditis, type I diabetes, celiac disease, Biermer's disease, multiple sclerosis, encephalomyelitis, eye inflammation, obesity-associated inflammation, age-related low-grade inflammation, Blau's syndrome, Alzheimer's disease, cardiovascular diseases, atherosclerosis, metabolic syndrome, or combinations thereof.
- 15 The composition of the present invention may comprise a mixture of sn-2 MAGs and sn-1(3) MAGs.

Depending on the nature of the fatty acid used as acyl-group in the sn-1(3) position such mixtures may form automatically through isomerisation.

- 20 Hence, the composition may comprise no more than 25 weight-%, preferably no more than 15 weight-% of the total MAGs as sn-2 MAGs.

- Unwanted isomerisation may be prevented or at least slowed down significantly by adjusting the pH to the neutral range and/or by keeping the temperature of the composition low.
- 25

Hence, the composition may have a pH in the range of about 5-8, preferably about 5-7.

The composition may also be to be stored at 8°C or below.

Isomerisation of the MAGs may further be prevented, even in the body after consumption by inhibiting the action of lipase B.

5 Hence, the composition may further comprise a lipase B inhibitor. Lipase B inhibitors are known to those of skill in the art. Edible lipase B inhibitors are preferred. "Edible" means that a material is approved for human or animal consumption.

10 The composition of the present invention may be any kind of edible composition. Preferably, the composition is a composition to be administered orally or enterally.

For example, the composition may be selected from the group consisting of a food product, an animal food product, a pharmaceutical composition, a nutritional composition, a
15 nutraceutical, a drink, a food additive or a medicament.

For example, the composition may be a liquid nutritional formula to be administered enterally, e.g., in hospitals.

The composition may also be a nutritional formulation to be administered to people above the age of 60.

20 The composition may also be a powdered composition to be reconstituted in milk or water.

If the composition is provided in the form of a powder, it may be a shelf stable powder. Shelf stability can be obtained, for example by providing the composition with a water activity
25 smaller than 0.2, for example in the range of 0.19-0.05, preferably smaller than 0.15. Water activity or a_w is a measurement of the energy status of the water in a system. It is defined as the vapor pressure of water divided by that of

pure water at the same temperature; therefore, pure distilled water has a water activity of exactly one.

The caloric density of the composition of the present invention may be adjusted to the needs of the patient.

- 5 For example, the composition in accordance with the present invention may have a caloric density in the range of 0,5 kcal/ml to 15 kcal/ml.

For patients suffering from malabsorption and/or low appetite rather high caloric densities may be preferred. For such
10 patients caloric densities in the range of 7-12 kcal/ml may be used.

The composition may also contain a protein source and/or a carbohydrate source. Easily digestible carbohydrates and/or proteins are preferred.

- 15 At least partially hydrolysed proteins are easier to digest and absorb. Hence, it may be desirable to supply at least partially hydrolysed proteins (degree of hydrolysis between 2 and 20%). If hydrolysed proteins are required, the hydrolysis process may be carried out as desired and as is known in the
20 art. For example, a protein hydrolysate may be prepared by enzymatically hydrolysing a protein fraction in one or more steps. For an extensively hydrolysed protein, the proteins may be subjected to triple hydrolysis using Alcalase 2.4L (EC 940459), then Neutrase 0.5L (obtainable from Novo Nordisk
25 Ferment AG) and then pancreatin at 55°C.

The amount of fatty acids in the composition of the present invention may be adjusted to the patients needs.

In therapeutic applications, the MAG derivatives are administered in an amount sufficient to at least partially cure or arrest the symptoms of the disease and its complications. An amount adequate to accomplish this is
5 defined as "a therapeutically effective dose". Amounts effective for this purpose will depend on a number of factors known to those of skill in the art such as the severity of the disease and the weight and general state of the patient.

In prophylactic applications, MAG derivatives are administered
10 to a patient susceptible to or otherwise at risk of a particular disease in an amount that is sufficient to at least partially reduce the risk of developing a disease. Such an amount is defined to be "a prophylactic effective dose". Again, the precise amounts depend on a number of patient specific
15 factors such as the patient's state of health and weight.

The compositions of the present invention are to be administered in an amount sufficient to provide the MAG derivatives in a therapeutically effective dose or a prophylactic effective dose.

20 For example, the composition may comprise the sn-1(3) MAG derivatives in an amount corresponding to about 1% to 40% of the energy of the composition, e.g., of about 5% to 40% of the energy of the composition.

Those skilled in the art will understand that they can freely
25 combine all features of the present invention described herein, without departing from the scope of the invention as disclosed. In particular, features described for the uses of the present invention may be applied to the compositions of the present invention and vice versa.

Further advantages and features of the present invention are apparent from the following Examples and Figures.

Figure 1 shows examples of EPA glycerides used in the present invention: a mixture of sn-1(3)-monoeicosapentaenoylglycerol.

- 5 Figure 2 shows the incorporation of EPA in red blood cells. Treatments: Control rats fed fish oil with or without Orlistat and rats fed with MAGs described in Figure 1. Values are means $\pm$ SEM (n=6).

Examples:

- 10 The concept was tested in a lipid maldigestion or malabsorption animal model. The maldigestion or malabsorption condition was obtained using Orlistat, a well known pancreatic and gastric lipases inhibitor. Animals were fed during 21 days with long-chain polyunsaturated fatty acid (LC-PUFAs)
- 15 supplements containing mainly eicosapentaenoic (EPA) acid. Fish oil was used as a source of triacylglycerols and the different EPA glycerides provided in Figure 1 and purchased from Cognis GmbH, Germany, were evaluated. Orlistat was given at a level sufficient to decrease lipid absorption by 40%. A
- 20 group receiving fish oil without Orlistat was used as a positive control. At different time intervals (D-3, D7, D14 and D21), fatty acid profile of red blood cell and plasma lipids were performed. At the end of the experiment, fatty acid profiles of different tissues were determined.
- 25 The main objective was to follow the level of EPA in red blood cell and plasma lipids. The main comparison evaluated was the difference in EPA level between groups receiving EPA containing MAGs (Figure 1) in combination with Orlistat and the positive control group (fish oil + Orlistat).

As an example, data obtained for EPA levels in red blood cell lipids at day 7 are reported in Figure 2. The statistical evaluation revealed that the use of Orlistat decrease EPA incorporation in red blood cells (comparison between the group receiving fish oil in combination or not with Orlistat). This comparison is very important since it corroborates the validity of the model. The level of EPA incorporated in red blood cells in animals receiving the MAGs containing EPA is statistically higher than the fish oil + Orlistat group (all P values lower than 0.05); and further surprisingly, even higher than the fish oil group.

This example clearly demonstrates that in condition of lipid maldigestion or malabsorption, the incorporation of LC-PUFA provided as triacylglycerols is reduced. However, if LC-PUFA are provided as sn-1(3) MAGs - also in combination with sn-2 MAGs, the incorporation in tissue is not altered and even improved, even in conditions of lipid maldigestion or malabsorption.

Claims :

1. Composition comprising a sn-1(3)-monoacylglycerol, wherein the acyl group is a fatty acid having anti-inflammatory properties for use in the treatment or prevention of inflammatory disorders, wherein the composition is to be administered to subjects suffering from a lipid maldigestion or malabsorption condition.
2. Composition for use in accordance with claim 1, wherein the fatty acid having anti-inflammatory properties is selected from the group consisting of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), α -linolenic acid (ALA), stearidonic acid, γ -linolenic acid (GLA), dihomogamma-linolenic acid (DGLA), n-3 docosapentanoic acid (DPA), sciadonic acid and juniperonic acid.
3. Composition for use in accordance with one of the preceding claims, wherein the sn-1(3)-monoacylglycerol is selected from the group consisting of sn-1(3)-monoeicosapentaenoylglycerol, sn-1(3)-monodocosahexaenoylglycerol, sn-1(3)-monooctadecatrienoylglycerol, sn-1(3)-monooctadecatetraenoylglycerol, sn-1(3)-monoeicosatrienoylglycerol, sn-1(3)-monodocosapentaenoylglycerol, sn-1(3)-monosciadonylglycerol, sn-1(3)-monojuniperonylglycerol or combinations thereof.
4. Composition for use in accordance with one of the preceding claims, wherein the sn-1(3)-monoacylglycerol is sn-1(3) monoeicosapentaenoylglycerol.
5. Composition for use in accordance with one of the preceding claims, wherein no more than 25 weight-%,

preferably no more than 15 weight-% of the total monoacylglycerols are sn-2 monoacylglycerols.

- 5 6. Composition for use in accordance with one of the preceding claims having a pH in the range of 5-8, preferably 5-7.
7. Composition for use in accordance with one of the preceding claims to be stored at 8°C or below.
- 10 8. Composition for use in accordance with one of the preceding claims further comprising a lipase B inhibitor.
- 15 9. Composition for use in accordance with one of the preceding claims, wherein the composition is selected from the group consisting of a food product, an animal food product, a pharmaceutical composition, a nutritional composition, a nutraceutical, a drink, a food additive or a medicament.
- 20 10. Composition for use in accordance with one of the preceding claims, wherein the composition has a caloric density in the range of 0,5 kcal/ml to 15 kcal/ml.
- 25 11. Composition for use in accordance with one of the preceding claims, wherein the sn-1(3)-monoacylglycerol derivative provides about 5% to 40% of the energy of the composition.
12. Composition for use in accordance with one of the preceding claims, wherein the sn-1(3)-monoacylglycerol derivative provides about 5% to 40% of the energy of the composition.

13. Composition in accordance with one of the preceding claims, wherein the composition contains a combination of different sn-1(3)-monoacylglycerol derivatives; for example with a ratio of n-3 to n-6 fatty acids of about 5:1 to about 15:1; for example about 8:1 to about 10:1.
14. Composition for use in accordance with one of the preceding claims for use in the delivery of fatty acids having anti-inflammatory properties.
15. Composition for use in accordance with one of the preceding claims, wherein the malabsorption condition is due to pancreatic insufficiency, bile salt deficiency, a mucosal disorder and/or a short gut.
16. Composition for use in accordance with one of the preceding claims, wherein the inflammatory disorder is selected from the group consisting of acute inflammations such as sepsis, and chronic inflammations such as inflammatory bowel disease, Crohn's disease, ulcerative colitis, necrotizing enterocolitis, skin inflammation, such as UV or chemical-induced skin inflammation, eczema, reactive skin, psoriasis, vitiligo, acne, inflammatory bowel syndrome, liver inflammation, alcoholic cirrhosis, allergy, atopy, bone inflammation, rheumatoid arthritis, systemic lupus, dermatomyositis, thyroiditis, type I diabetes, celiac disease, Biermer's disease, multiple sclerosis, encephalomyelitis, eye inflammation, obesity-associated inflammation, age-related low-grade inflammation, Blau's syndrome, Alzheimer's disease, cardiovascular diseases, atherosclerosis, metabolic syndrome.