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## MICROBIAL OIL MIXTURES AND USES THEREOF

This invention relates to blends or mixtures of polyunsaturated fatty acid-containing microbial oils and to uses thereof. In a specific preferred embodiment, this invention concerns the use of such oils as an additive or supplement for human diets, for example, as an additive to infant formula.

It long has been known that long chain polyunsaturated fatty acids (PUFAs) are essential to the human diet, particularly during periods of rapid tissue growth. Sanders et al, Am. J. Clin. Nutr., 31:805-813 (1978). Certain of these long chain acids, such as arachidonic acid (ARA), cannot be synthesized de novo in humans. Only by metabolizing linoleic acid (LOA), which is converted to gamma linolenic acid (GLA), and then to ARA<sup>1</sup> can the human body produce ARA. LOA, in turn, is an essential acid which can only be obtained from dietary sources. Additionally, the presence of eicosapentaenoic acid (EPA) in the diet inhibits the metabolic conversion of LOA to ARA. Carlson, et al., INFORM, 1:306 (1990). ARA and docosahexaenoic acid (DHA) are critical elements of muscle, organ and vascular tissues.

Infancy is the most significant period of rapid growth in a human's life. An infant can increase its body weight by three times or more during its first year of life. Accordingly, it is critical that the infant receive adequate amounts of PUFAs to insure

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proper structural and organ development. Human breast milk contains high levels of PUFAs in which the ratio of ARA to EPA is typically about 20:1. However, many women choose not to breast feed their infants for  
5 either part or all of the first year of the infant's life.

As recognized by Clandinin et al., U.S. Patent 4,670,285, incorporated herein by reference, available infant formulas are deficient in long chain ( $C_{20}$  and  $C_{22}$ )  
10 PUFAs. Clandinin et al. disclose an infant formula prepared from a blend of vegetable oil and egg yolk lipid and/or fish oil which can provide a total fat composition comparable to that of human breast milk. A preferable composition comprises from 75 to 95 parts by  
15 weight egg yolk and 5 to 25 parts vegetable oil. This composition is the entire lipid content of the infant formula and it is not economical to prepare. Additionally, the infant formula disclosed by Clandinin et al. results in an EPA level which is 16 times higher  
20 than the level of EPA in human breast milk and an ARA level which is only one quarter that of breast milk.

DE 3603000A1 (Milupa) discloses a computer profile of a highly polyunsaturated acid fat mixture and discusses the use of such a mixture to produce infant  
25 formulas. Sources of the fatty acids are listed as certain types of macroalgae (i.e. seaweed), fish oil, organ fats from beef and pork, and highly refined egg yolk oil. In addition to DHA from fish oil, a potential source of DHA and ARA is said to be  
30 macroalgae, but only of the seaweed types. There is no suggestion to use microbes of any type, much less microbial oil.

Methods of producing microbial oils are disclosed in the following references, each of which is

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incorporated herein by reference. Co-pending U.S. Patent Application 07/496,572, filed March 21, 1990, discloses the production of eicosapentaneic acid-containing single cell oils (EPASCO). Co-pending U.S. Patent Application 07/479,135, filed February 13, 1990, discloses the production of docosahexaneic acid-containing single cell oil (DHASCO). Co-pending U.S. Patent Application 07/645,454 relates to the production of arachidonic acid-containing single cell oil (ARASCO). EP322,227 also discloses a microbial oil production system. None of these references teach the use of blends containing unmodified microbial oils as a dietary supplement, or the use of a blend of microbial oils as an additive to existing infant formula to provide that formula with a long chain PUFA composition similar to breast milk.

Accordingly, it is an object of the present invention to provide a PUFA-enriched additive, the composition of which when added to commercial infant formula will provide desired long chain PUFAs in amounts comparable to the amounts of those PUFAs found in human breast milk.

It is an additional object of the present invention to provide an economical method of producing the above-described composition.

These, and other, objects are satisfied by the present invention as described herein.

#### Summary of the Invention

This invention relates to the use of microbial oils which contain long chain polyunsaturated fatty acids. Additionally, in various embodiments, fish oil and/or vegetable oils can be blended with such microbial oils to form desired compositions. The

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compositions can be used as dietary supplements, particularly as additives for infant formula, as well as for pharmaceutical and cosmetic applications.

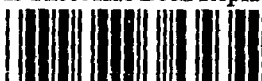
5 The invention also relates to economically viable processes for altering the long chain polyunsaturated fatty acid composition of infant formula and/or baby food. Preferably, the altered composition resembles that of human breast milk.

10 Detailed Description of the Preferred Embodiment of the Invention

Broadly stated, the present invention concerns blends, or mixtures, containing unmodified microbial oils. As used herein, "unmodified" means not chemically or covalently altered. It will be  
15 understood that throughout this specification references to "microbial oil" or "oil" mean, unless otherwise specifically stated, unmodified oil. "Microbial oils" or "single cell oils" are those oils naturally produced by microorganisms during their  
20 lifespan. Such oils can be high in long chain PUFAs. The applicant has discovered that certain of these oils, when blended with other microbial oils, fish oils, vegetable oils, or any combination thereof, can produce a composition useful for dietary,  
25 pharmaceutical or cosmetic purposes.

Various microbial oils, for example, can be obtained by, for example, the processes disclosed in above-referenced U.S. Patent Applications 07/496,572, 07/479,135, EP322,227 (Yamada et al., Suntory) or U.S.  
30 Patent Application 07/645,454. The disclosure of each of these references is specifically incorporated by reference herein.

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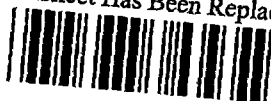
It is to be understood that the present invention encompasses the use of a single-microbial oil containing at least two desirable PUFAs, such as ARA and DHA. The oils specifically disclosed and utilized herein, however, each contain a single desirable PUFA.

Any non-toxic, PUFA-containing microbial oil can be used in the present invention. The most preferred microbial oils are those rich in an omega-3 or omega-6 PUFA, especially DHA, GLA or ARA. These PUFAs typically are missing from, or are inadequately provided in, dietary supplements such as infant formulas or baby food. "Infant formula" as used herein means an enteral nutritional product which can be substituted for human breast milk in feeding infants and typically is composed of a desired percentage of fat mixed with desired percentages of carbohydrates and proteins in an aqueous solution. Frequently micronutrients, such as trace metals and vitamins or other desired additives are present. Examples of such micronutrients and other additives are disclosed by Clandinin et al., U.S. Patent No. 4,670,285, the disclosure of which is incorporated herein by reference.

In the present invention, types of oils from different microbes can be mixed together to obtain a desired composition. Alternatively, or additionally, PUFA-containing microbial oil can be blended with fish oil, vegetable oil or a mixture of both to obtain a desired composition.

An objective in mixing the oils is to obtain an additive which will provide an infant formula with a desired omega-3 and omega-6 PUFA composition similar to that found in breast milk. While the proportion of the desired fatty acids in a microbial oil can vary, this

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proportion can easily be determined and the amount of oil adjusted to provide the desired amount of PUFA. Similarly, the percentage of desired PUFA in fish oil or vegetable oils can easily be determined and the amount of the oil to be added can be adjusted as necessary to achieve the desired results.

"Fish oils" are those oils obtained from fish. Such oils typically contain DHA in amounts ranging from 3% to about 20%. Typically, however, fish oils also contain EPA which depresses the production of ARA in the body. The addition of a microbial oil containing high levels of ARA to fish oil-containing compositions substantially overcomes that problem.

"Vegetable oil" includes all those oils from plants which contain long chain PUFAs. Typically, vegetable oils do not contain long chain PUFAs (PUFAs at least 20 carbons long), which is why animal organ oils are usually characterized as the source of PUFAs. Thus, vegetarians, especially vegetarian mothers, can have a diet containing inadequate amounts of PUFAs. Vegetable oils known to contain PUFAs may contain GLA. GLA is a C18:3 omega-6 PUFA. Such oils include black currant seed oil, borage oil and primrose oil. While GLA is the metabolic precursor to ARA, the process of conversion is very slow, requiring the participation of the enzyme  $\Delta 6$ -desaturase. This enzyme is present in humans in very low levels. Burre, et al., Lipids, 25:354-356 (1990). Thus, it would be preferable to provide the body with ARA rather than its precursor, GLA.

Methods for isolating vegetable oils are known to those of skill in the art and do not comprise a part of the present invention. Additionally, certain fungi

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produce PUFA-containing oils. For example, *Mucor* species produce a GLA-containing oil.

5 DHASCO, defined herein as docosahexanoic acid-containing single cell oil, can be obtained, for example, from *Cryptocodinium cohnii* as disclosed in above-referenced U.S. application 07/479,135. DHA is a C22:6 omega-3 long chain PUFA.

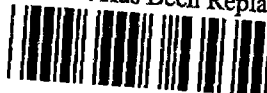
10 EPASCO, defined herein as eicosapentanoic acid-containing single cell oil, can be obtained, for example, from *Nitzschia alba* as disclosed in above-referenced U.S. application 07/496,572. EPA is a C20:5 omega-3 long chain PUFA.

15 ARASCO, defined herein as arachidonic acid-containing single cell oil, can be obtained from species such as *Pythium insidiosum*, or *Mortierella alpina*, as described in U.S. application 07/645,454. ARA is a C20:4 omega-6 long chain PUFA.

20 Another aspect of the invention discloses a process for supplementing or altering the composition of commercially available infant formula so as to provide them with a PUFA composition more nearly like that typically contained in human breast milk.

25 "Typical" as used herein refers to the average amounts of PUFAs measured. One of the advantages of the present invention is that, if desired, a nursing mother choosing to switch to formula can have her breast milk analyzed for PUFA content. Then, an additive for a commercially available formula which will supply comparable amounts of PUFAs can be specifically  
30 designed. Long chain PUFA-containing microbial oils from at least two microorganisms can be obtained and blended together to provide the desired composition. The blend then can be added to an infant formula. Preferably, an amount of the blend effective to provide

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an amount of the desired PUFAs substantially similar to that found in human breast milk will be provided.

Typically, human breast milk contains from about 0.5 to 0.6% of its fatty acid content as ARA, from about 0.15 to about 0.36% of its fatty acid content as DHA and from about 0.03 to about 0.13% of its fatty acid content as EPA. Thus, a preferred ratio of ARA:DHA:EPA is from about 5:1:1 to about 20:10:1 respectively. Amounts of oils providing approximately these ratios of PUFAs can be determined without undue experimentation by those of skill in the art.

In a preferred embodiment, the microbial oils include ARASCO and DHASCO and EPASCO or any combination thereof. It is also preferred to use oil from microbes of the genera *Mortierella*, *Pythium*, *Cryptocodinium*, and *Nitzschia* or any combination thereof. Particularly preferred species from these genera are *M. alpina*, *P. insidiosum*, *C. cohnii* and *N. alba*. This preferred embodiment would provide an acceptable alternative for vegetarians, including breast-feeding or pregnant vegetarian women.

If desired, fish oil can be blended, or mixed, with any combination of, or individual, microbial oil to produce a composition which, when subsequently added to infant formula will alter the PUFA content thereof in a desirable manner. Such a composition would not be suitable for a strict vegetarian intake. A preferred fish oil is specially processed Menhaden Oil (produced by Zapata Hayne, Inc.) which typically contains about 9% DHA. Of course, other fish oils also can be used.

When DHASCO is to be blended with ARASCO, and no other PUFA-containing oils are to be utilized, it is desirable to blend sufficient amounts of the oils to provide from about 1 to about 5 parts DHA with from

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about 2 to about 12 parts ARA. A most preferred ratio of DHA to ARA is 1:3 respectively.

As another example, Menhaden fish oil, as noted above, typically contains about 9% by weight DHA.

5 ARASCO typically contains about 20 - 40% by weight ARA. DHASCO typically contains about 25 - 40% by weight DHA. It has been found that a blend of 1 part Menhaden oil containing about 9% by weight DHA with 10 parts ARASCO containing about 33% by weight ARA and 3 parts DHASCO  
10 containing about 35% by weight DHA, when added to infant formula, causes the infant formula to closely approximate the ARA and DHA content of human breast milk. Other ratios can be readily calculated.

In another embodiment of the present invention is  
15 disclosed a process for making a supplement for infant formula or baby food which entails blending a DHA-containing oil with a GLA-containing oil. It is to be understood that, in general, any combination of GLA-, EPA-, ARA- or DHA-containing oils, with or without fish  
20 oil, can be used. The source of the GLA can be a vegetable oil, such as primrose, black currant or borage oil, or a microbial oil such as the oil from *Mucor javanicus* or *Mortierella isabellina*, for example. Table 1 sets forth the GLA composition of such oils.

25 In a preferred aspect of this embodiment, about 1 part of Menhaden oil containing about 9% DHA, about 4 parts of GLA-containing oil containing about 18% GLA from black currant seed, and about 1 part of DHASCO containing about 33% DHA are blended together. Other  
30 ratios can be selected as desired.

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Table 1. Fatty acids of commercially available oils containing GLA (from Lawson and Hughes, 1988 and Suzuki, 1989)

| 5  | Fatty acyl group             | Relative % of total acyl groups in oil from: |                                 |                  |               |        |
|----|------------------------------|----------------------------------------------|---------------------------------|------------------|---------------|--------|
|    |                              | <u>Mucor javanicus*</u>                      | <u>Mortierella isabellina**</u> | Evening Primrose | Black-currant | Borage |
| 10 | 14:0                         | 1.0                                          | 0.7                             | -                | -             | -      |
|    | 14:1                         | 0.1                                          | -                               | -                | -             | -      |
|    | 16:0                         | 18.6                                         | 27.2                            | 5.9              | 6.9           | 10.7   |
|    | 16:1                         | 1.0                                          | 0.9                             | -                | -             | -      |
|    | 18:0                         | 7.1                                          | 5.7                             | 1.8              | 1.3           | 3.0    |
| 15 | 18:1                         | 39.9                                         | 43.9                            | 7.5              | 10.8          | 15.4   |
|    | 18:2                         | 8.9                                          | 12.0                            | 74.8             | 46.7          | 38.1   |
|    | $\gamma$ -18:3 ( $\omega$ 6) | 17.9                                         | 8.3                             | 9.3              | 15.9          | 24.8   |
|    | $\alpha$ -18:3 ( $\omega$ 3) | -                                            | -                               | -                | 13.0          | -      |
|    | 18:4 ( $\omega$ 3)           | -                                            | -                               | -                | 2.9           | -      |
| 20 | 20:0                         | -                                            | 0.6                             | -                | -             | -      |
|    | 20:1 ( $\omega$ 9)           | -                                            | -                               | -                | -             | -      |
|    | 22:0                         | -                                            | 0.1                             | -                | -             | 4.0    |
|    | 22:1 ( $\omega$ 9)           | -                                            | 0.2                             | -                | -             | -      |
|    | 24:0                         | 0.6                                          | -                               | -                | -             | 2.2    |

\* Produced by J. & E. Sturge Ltd., Selby, N. Yorks., U.K.

\*\* Produced by Idemitsu Petro Chemical Co. Ltd., Tokyo, Japan.

Lawson - Lipids 23:313-317 (1988)

Suzuki - In Biotechnology for the Fats and Oils Industry  
p.110-116. Amer Oil Chem. Soc. Press (1989).

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5 A composition including a blend of any combination of the above-described microbial oils with or without either, or both, fish oil and vegetable oil is another aspect of the present invention. While the composition includes any ratios of the oils, the ratios previously described are preferred.

10 In another preferred embodiment, the composition serves as a nutritional supplement. Typically, such supplements are encapsulated, such as in gelatin capsules. Such capsules provide an easy form of administration to persons having a need for supplementation, such as pregnant or nursing women. However, parenteral administration is a viable option and in one embodiment the composition comprises the fat component of a total parenteral nutritional formula. 15 Such formulas are known and commercially available.

As will be understood, the composition of the present invention is particularly useful as a dietary supplement for pregnant or nursing women. Vegetarian women, in particular, may require increased amounts of DHA and ARA, yet have been precluded from obtaining such in the past because the only available sources were animal. 20

The invention having been previously described in general, reference is now had to the following non-limiting examples for illustrative purposes only. 25

#### Examples

##### Example 1. Preparation of *P. insidiosum* lipid

30 In an 80 liter (gross volume) fermentor, 51 liters of tap water, 1.2 kg glucose, 240 grams of yeast extract and 15 ml of MAZU 210S<sup>®</sup> antifoam were combined. The fermentor was sterilized at 121°C for 45 minutes. An additional 5 liters of condensate water were added

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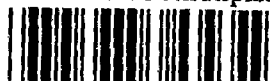
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during the sterilization process. The pH was adjusted to 6.2, and approximately 1 liter of inoculum (at a cell density of 5-10g/l) of Pythium insidiosum (ATCC #28251) then was added. The agitation rate was adjusted to 125 RPM (250 cm/sec tip speed) and the aeration rate was set at 1 SCMF (standard cubic feet per minute). At hour 24 in the operation the aeration rate was increased to 3 SCFM. At hour 28 an additional 2 liters of 50% glucose syrup (1 kg glucose) were added. At hour 50 the fermentor was harvested, resulting in a yield of about 2.2 kg wet weight (approximately 15 g dry weight) per liter. Harvested biomass was squeezed to a high solids cake (50% solids) on a suction filter before freeze drying. The dried biomass was ground with a mortar and pestle and extracted with 1 liter of hexane per 200 grams of dry biomass at room temperature under continuous stirring for 2 hours. The mixture then was filtered and the filtrate evaporated to yield about 5-6 grams of crude oil per 100 grams of dry biomass. The biomass then was reextracted with 1 liter of ethanol per 20 grams of dry biomass for 1 hour at room temperature, filtered, and the solvent evaporated yielding an additional 22 grams of crude oil per 100 grams of dry biomass. The second fraction was predominantly phospholipids whereas the first fraction contained a mixture of phospholipids and triglycerides. The combined fractions produced an oil containing about 30-35% arachidonic acid and no detectable EPA.

### 30 Example 2. Preparation of *M. alpina* lipid

*Mortierella alpina* (ATCC #42430) was grown in a 2 liter shake flask containing 1 liter of tap water and

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20 grams of potato dextrose medium. The flask was under constant orbital agitation and was maintained at 25°C for seven days. After harvesting by centrifugation, the biomass was freeze dried yielding about 8 grams of lipid-rich mycelia. The mycelia was extracted using hexane as in example #1 and about 2.4g of crude oil resulted. This oil contains about 23% arachidonic acid.

### Example 3

Into a 30-liter working volume STF was loaded a medium of one quarter strength artificial seawater. Six liters of IO were combined with 18 liters of tap water. The fermentor containing the medium was sterilized and cooled to 28°C. Four hundred ml of concentrated YE (455g/l), 900 ml of glucose syrup (400 g/l) and one liter of inoculum from a seed fermentor containing about  $2 \times 10^7$  *C. cohnii* cells/ml or a biomass of 20 g/liter (yielding a final concentration of about  $10^5$  cells/ml or a biomass of about 700 mg/liter), were added to the medium. The *C. cohnii* cells, designated MK8840, were obtained from the American Type Culture Collection as ATCC 40750. Agitation was set at 120 cm/sec tip speed and aeration was set at 1 VVM (30 liters per minute). Additional glucose syrup (900 ml) was added after 30 hours and another 4.2 liters over the next 42 hours. Thus 6 liters of glucose syrup were added in total. Concentrated YE solution (400 ml) was added at hour 6 and another 1.2 liters were added over the next 48 hours until a total of 2.0 liters had been added. To maintain the D.O. at greater than 20%, at 24 hours the agitation tip speed was increased to 150 cm/sec and at 48 hours to 160 cm/sec. At 72 hours, the tip speed was increased to 200 cm/sec and the culture

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was permitted to grow for an additional time sufficient to convert the final charge of glucose into cellular oil. The culture was then harvested by centrifugation with the cell pellet retained. The harvested pellet of  
5 cells was frozen and dried (lyophilized) to about a 4% moisture content. Hexane (2.8 liters) was added to the dried biomass and stirred in a glass kettle for 1.5 hours at 50°C. A rotary evaporator was used to remove the hexane, producing about 175 g of crude DHA-  
10 containing oil.

Example 4

Into a conventional 30 liter stirred tank fermentor (STF) is added the nutrient medium of Table A, exclusive of the vitamins, glucose and  
15 silicate. The fermentor is equipped with a Rushton-type turbine agitator. The STF and the medium are sterilized. After cooling the medium to about 30°C, the vitamins are added, followed by the addition of sufficient amounts of 40% glucose syrup to provide a  
20 glucose concentration of about 80 g/l. Concentrated sodium metasilicate pentahydrate (100 g/l) is then added to provide a total silicate concentration of about 200 mg/l. Next, the inoculating amount of culture of *N. alba* cells obtained from the American  
25 Type Culture Collection as ATCC 40775, is added in an amount approximately equal to 5% of the total volume of the fermentor, e.g. 1.5 liters/30 liters. Agitation is commenced with the tip speed set to 85-90 cm/sec and air sparging at 1 VVM started. Over about 16 hours an  
30 additional charge of concentrated metasilicate (0.53 liters) is added and the agitation speed increased to 126 cm/sec. Over about the next 24 hours, more concentrated silicate (0.83 liters) is added.

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Agitation speed again is increased to about 180-185  
cm/sec. Over about the next 3 hours an additional 0.15  
liters of concentrated metasilicate is added. Thus,  
the total amount of metasilicate added is about 156  
5 grams or about 1.6 liters of concentrated solution. At  
about 48 hours additional glucose (about 5 liters) is  
added, for a total glucose addition of about 4.8 Kg or  
about 12 liters of 40% glucose syrup. The culture is  
permitted to grow for an additional 16 hours,  
10 maintaining the agitation speed and aeration rate.  
Then, the fermentor is harvested using a Sharples  
continuous flow centrifuge producing a biomass density  
of approximately 45-48 grams dry weight per liter. The  
resulting pellet, about 20-38% solids, is removed and  
15 frozen to about -20°C. A vacuum tray drier is used to  
remove water from the pellet. The single cell oil  
pellet then is extracted with hexane. The hexane  
subsequently is removed by distillation leaving the  
extracted single cell oil.

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Ingredients needed for 2x30L Fermentors and 2x350L Fermentors.

|                            | <u>Recipe</u>                                                                                                | <u>Total</u>     |                   |
|----------------------------|--------------------------------------------------------------------------------------------------------------|------------------|-------------------|
|                            |                                                                                                              | <u>30L-Batch</u> | <u>350L-Batch</u> |
| 5                          | 19g/L I.O. (Instant Ocean®)                                                                                  | 570g             | 6.65Kg            |
|                            | 3g/L NaNO <sub>3</sub>                                                                                       | 90g              | 1.05Kg            |
|                            | 0.5g/L NaH <sub>2</sub> PO <sub>4</sub> ·H <sub>2</sub> O                                                    | 15g              | 175g              |
| 10                         | 0.2g/L Na <sub>2</sub> SiO <sub>3</sub> ·5H <sub>2</sub> O                                                   | 6g               | 70g               |
|                            | 6ml/L f/2 TM (trace metals)                                                                                  | 180ml            | 2.1L              |
|                            | 60mg/L H <sub>3</sub> BO <sub>3</sub>                                                                        | 1.8g             | 21g               |
|                            | 6mg/L Na <sub>2</sub> SeO <sub>3</sub>                                                                       | 180mg            | 2.1g              |
|                            | 10mg/L NaF                                                                                                   | 300mg            | 3.5g              |
| 15                         | 40mg/L SrCl <sub>2</sub> ·6H <sub>2</sub> O                                                                  | 1.2g             | 14g               |
|                            | 150mg/L KBr                                                                                                  | 4.5g             | 52.5g             |
|                            | 0.5g/L KCl                                                                                                   | 15g              | 175g              |
|                            | 2ml/L B <sub>6</sub> TM (trace metals)                                                                       | 60ml             | 700ml             |
| <u>After Sterilization</u> |                                                                                                              |                  |                   |
| 20                         | 0.1ml/L of 0.1mg/ml B <sub>12</sub>                                                                          | 3ml              | 35ml              |
|                            | 0.1ml/L of 0.1mg/ml Biotin                                                                                   | 3ml              | 35ml              |
|                            | 2ml/L of 1mg/ml Thiamine HCl                                                                                 | 60ml             | 700ml             |
|                            | Glucose: (1) Start with 80g/L (40% stock solution)                                                           | 6L               | 70L               |
| 25                         | (2) Add another 40g/l 1 and 2 (additional 6 liters on day 2)                                                 | 3L               | 35L               |
| 30                         | Silicate: Add 60ml/liter of 100g/liter stock solution add additional amounts of stock solution over 48 hours | 1.8L             | 21L               |

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Example 5. Preparation of Oil Mix #1 and addition to infant formula.

The first mixture represents a totally vegetarian source of an arachidonic and docosahexaenoic acid supplement. This supplement would be considered acceptable to persons restricted to a vegetarian diet. Sanders et al. (Amer. J. Clin. Nutr. 31:805; 1978) have reported that the DHA levels in the breast milk of vegetarian mothers are depressed. Enteral supplementation of a blend of DHA single cell oil and ARA single cell oil will elevate the serum and, hence, breast milk levels of DHA to that of omnivorous mothers. This blend is prepared by mixing one part DHASCO containing about 35% DHA (obtained from *Cryptocodinium cohnii* as described in Example 3) with three parts ARASCO containing about 33% ARA (obtained from *Pythium insidiosum* as described in Example 1). The resulting mixture, or blend, has the fatty acid composition shown in Table 2. The blend is mixed in a ratio of one part blend to forty parts of the oils regularly in infant formula, typically about 2.8 - 3.0 grams per 100 ml of formula. At a normal fat content of 30g fat per liter of Similac® infant formula, this corresponds to the addition of 750 mg per liter of prepared formula. This supplement provides ARA and DHA levels equivalent to human breast milk.

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Table 2. Composition of a blend of DHA oil and ARA oil in proportions of 1:3 by weight.

|    | <u>Fatty Acid</u> | <u>oil mix #1</u> | <u>Infant formula</u> | <u>formula + mix #1</u> | <u>breast milk</u> |
|----|-------------------|-------------------|-----------------------|-------------------------|--------------------|
|    | 8:0 + 10:0        | 0.00              | 41.8                  | 40.78                   | 1.74               |
| 5  | 12:0 + 14:0       | 13.63             | 20.7                  | 20.53                   | 14.95              |
|    | 16:0              | 17.05             | 6.8                   | 7.05                    | 19.82              |
|    | 16:1              | 7.88              | 0.2                   | 0.39                    | 3.20               |
|    | 18:0              | 0.00              | 2.3                   | 2.24                    | 5.91               |
|    | 18:1              | 7.48              | 10.0                  | 9.94                    | 34.82              |
| 10 | 18:2 n6           | 7.20              | 17.4                  | 17.15                   | 16.00              |
|    | 18:3 n3           | 2.25              | 0.9                   | 0.93                    | 0.62               |
|    | 18:3 n6           | 4.50              | ---                   | 0.11                    | 0.00               |
|    | 20:1              | ---               | 0.1                   | 0.10                    | 1.10               |
|    | 20:2 n6           | ---               | ---                   | 0.00                    | 0.61               |
| 15 | 20:3 n6           | ---               | ---                   | 0.00                    | 0.42               |
|    | 20:4 n6           | 24.75             | ---                   | 0.60                    | 0.59               |
|    | 20:5 n3           | ---               | ---                   | 0.00                    | 0.03               |
|    | 22:1              | ---               | ---                   | 0.00                    | 0.10               |
|    | 22:4 n6           | ---               | ---                   | 0.00                    | 0.21               |
| 20 | 22:5 n6           | ---               | ---                   | 0.00                    | 0.22               |
|    | 22:6 n3           | 8.98              | ---                   | 0.22                    | 0.19               |

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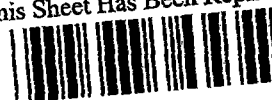
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Example 6. Preparation of Oil Mix #2 and addition to infant formula.

This mixture represents a totally vegetarian source of long chain PUFAs and would be considered acceptable to persons restricted to a vegetarian diet. This blend is prepared by mixing three parts DHASCO containing about 35% DHA (obtained from *Cryptocodinium cohnii* as described in Example 3) with ten parts ARASCO containing about 33% ARA (obtained from *Pythium insidiosum* as described in Example 1) and five parts EPASO containing about 5% EPA (obtained from *N. alba* as described in Example 4). The resulting mixture, or blend, has the fatty acid composition shown in Table 3. The blend is mixed in a ratio of one part blend to thirty parts of the oils regularly in infant formula. At a normal fat content of 30g fat per liter of Similac® infant formula, this would correspond to the addition of one gram per liter of prepared formula. This supplement provides ARA, DHA and EPA levels equivalent to human breast milk.

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Table 3. Composition of a blend of DHA oil, ARA oil and EPA oil in proportions of 3:10:5 by weight.

|    | <u>Fatty Acid</u> | <u>oil mix #2</u> | <u>Infant formula</u> | <u>formula + mix #2</u> | <u>breast milk</u> |
|----|-------------------|-------------------|-----------------------|-------------------------|--------------------|
| 5  | 8:0 + 10:0        | 0.00              | 41.8                  | 40.45                   | 1.74               |
|    | 12:0 + 14:0       | 16.64             | 20.7                  | 20.57                   | 14.95              |
|    | 16:0              | 21.61             | 6.8                   | 7.28                    | 19.82              |
|    | 16:1              | 6.55              | 0.2                   | 0.40                    | 3.20               |
|    | 18:0              | 0.28              | 2.3                   | 2.23                    | 5.91               |
| 10 | 18:1              | 12.91             | 10.0                  | 10.09                   | 34.82              |
|    | 18:2 n6           | 5.87              | 17.4                  | 17.03                   | 16.00              |
|    | 18:3 n3           | 1.88              | 0.9                   | 0.93                    | 0.62               |
|    | 18:3 n6           | 3.48              | --                    | 0.11                    | 0.00               |
|    | 20:1              | --                | 0.1                   | 0.10                    | 1.10               |
| 15 | 20:2 n6           | --                | --                    | 0.00                    | 0.61               |
|    | 20:3 n6           | 0.19              | --                    | 0.01                    | 0.42               |
|    | 20:4 n6           | 18.52             | --                    | 0.60                    | 0.59               |
|    | 20:5 n3           | 0.76              | --                    | 0.02                    | 0.03               |
|    | 22:1              | --                | --                    | 0.00                    | 0.10               |
| 20 | 22:4 n6           | 0.11              | --                    | 0.00                    | 0.21               |
|    | 22:5 n6           | --                | --                    | 0.00                    | 0.22               |
|    | 22:6 n3           | 6.24              | --                    | 0.20                    | 0.19               |

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Example 7. Preparation of Oil Mix #3 and addition to infant formula.

This mixture is a blend of ARASCO with fish oils. Oil mixture #3 is prepared by adding one part specially processed Menhaden Oil (Zapata Hayne Inc.) containing about 9% DHA to one part of ARASCO, obtained from *Pythium insidiosum* as described previously containing about 33% ARA. The resultant fatty acid composition is shown in Table 4. This blend is mixed in a ratio of one part blend to thirty parts of the oils regularly in infant formula. At a normal fat content of 30 g fat per liter of infant formula, this corresponds to the addition of 1 gram per liter of prepared formula. This supplement provides ARA and DHA levels equivalent to human breast milk, but the EPA levels are about eight-fold higher than those in breast milk.

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Table 4. Composition of a blend of SPMO\* and ARA oil in proportions of 1:1 by weight.

|    | <u>Fatty Acid</u> | <u>oil mix #3</u> | <u>Infant formula</u> | <u>formula + mix #3</u> | <u>breast milk</u> |
|----|-------------------|-------------------|-----------------------|-------------------------|--------------------|
|    | 8:0 + 10:0        | 0.0               | 41.8                  | 40.45                   | 1.74               |
|    | 12:0 + 14:0       | 10.2              | 20.7                  | 20.36                   | 14.95              |
| 5  | 16:0              | 15.5              | 6.8                   | 7.08                    | 19.80              |
|    | 16:1              | 11.5              | 0.2                   | 0.56                    | 3.20               |
|    | 18:0              | 1.41              | 2.3                   | 2.27                    | 5.91               |
|    | 18:1              | 8.79              | 10.0                  | 9.96                    | 34.82              |
|    | 18:2 n6           | 5.57              | 17.4                  | 17.02                   | 16.00              |
| 10 | 18:3 n3           | 2.31              | 0.9                   | 0.95                    | 0.62               |
|    | 18:3 n6           | 3.00              | --                    | 0.10                    | 0.00               |
|    | 20:1              | 0.78              | 0.1                   | 0.12                    | 1.10               |
|    | 20:2 n6           | 0.00              | --                    | 0.00                    | 0.61               |
|    | 20:3 n6           | 0.00              | --                    | 0.00                    | 0.42               |
| 15 | 20:4 n6           | 17.52             | --                    | 0.57                    | 0.59               |
|    | 20:5 n3           | 7.76              | --                    | 0.25                    | 0.03               |
|    | 22:1              | 0.00              | --                    | 0.00                    | 0.10               |
|    | 22:4 n6           | 0.00              | --                    | 0.00                    | 0.21               |
|    | 22:5 n6           | 1.21              | --                    | 0.04                    | 0.22               |
| 20 | 22:6 n3           | 4.57              | --                    | 0.15                    | 0.19               |

\* Specially Processed Menhaden Oil.

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Example 8. Preparation of Oil Mix #4 and addition to  
infant formula

Oil mixture #4 was developed to utilize GLA in  
place of arachidonic acid. This blend was prepared by  
5 mixing one part specially prepared Menhaden oil  
containing about 9% DHA (Zapata Hayne Inc.) with four  
parts black currant seed oil containing about 18% GLA  
and one part DHASCO containing about 35% DHA. The  
resultant fatty acid composition is shown in Table 5.  
10 This blend is mixed in a ratio of one part blend to  
forty parts of the oils regularly in infant formula.  
At a normal fat content of 30g fat per liter, this  
would correspond to the addition of 750 mg per liter of  
prepared formula. This supplement provides EPA and DHA  
15 levels equivalent to human breast milk. The ARA levels  
are about one tenth the level in human breast milk.  
However, the GLA levels are twenty to fifty times  
higher than the GLA levels in breast milk which  
typically are minute.

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Table 5. Composition of a blend of SPMO, BCO and DHA oil in proportions of 1:4:1 by weight.

|    | <u>Fatty Acid</u> | <u>oil mix #4</u> | <u>Infant formula</u> | <u>formula + mix #4</u> | <u>breast milk</u> |
|----|-------------------|-------------------|-----------------------|-------------------------|--------------------|
| 5  | 8:0 + 10:0        | 0.0               | 41.8                  | 40.78                   | 1.74               |
|    | 12:0 + 14:0       | 4.83              | 20.7                  | 20.31                   | 14.95              |
|    | 16:0              | 11.86             | 6.8                   | 6.92                    | 19.80              |
|    | 16:1              | 2.09              | 0.2                   | 0.25                    | 3.20               |
|    | 18:0              | 1.34              | 2.3                   | 2.28                    | 5.91               |
| 10 | 18:1              | 10.98             | 10.0                  | 10.02                   | 34.82              |
|    | 18:2 n6           | 31.39             | 17.4                  | 17.74                   | 16.00              |
|    | 18:3 n3           | 8.94              | 0.9                   | 1.10                    | 0.62               |
|    | 18:3 n6           | 10.60             | --                    | 0.26                    | 0.00               |
|    | 20:1              | 0.26              | 0.1                   | 0.10                    | 1.10               |
| 15 | 20:2 n6           | --                | --                    | 0.00                    | 0.61               |
|    | 20:3 n6           | --                | --                    | 0.00                    | 0.42               |
|    | 20:4 n6           | 0.34              | --                    | 0.06                    | 0.59               |
|    | 20:5 n3           | 2.59              | --                    | 0.00                    | 0.03               |
|    | 22:1              | --                | --                    | 0.00                    | 0.10               |
| 20 | 22:4 n6           | --                | --                    | 0.00                    | 0.21               |
|    | 22:5 n6           | 0.40              | --                    | 0.01                    | 0.22               |
|    | 22:6 n3           | 7.51              | --                    | 0.18                    | 0.19               |



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Example 9. Preparation of Oil Mix #5 and addition to infant formula

Oil mixture #5 was developed to best approximate the composition of DHA, ARA and EPA of human breast milk. This oil blend was prepared by mixing one part specially prepared Menhaden oil containing about 9% DHA (Zapata Hayne Inc.) with ten parts of ARASCO containing about 33% ARA and three parts DHASCO containing about 35% DHA. The resultant fatty acid composition is shown in Table 6. This blend is mixed in a ratio of one part blend to forty parts of the oils regularly in infant formula. At a normal fat content of 30g fat per liter of infant formula, this corresponds to the addition of 750 mg per liter of prepared formula. This supplement provides EPA, DHA and ARA levels substantially equivalent to those levels in human breast milk.

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Table 6. Composition of a blend of SPMO, ARA oil and DHA oil in proportions of 1:10:3 by weight.

|    | <u>Fatty Acid</u> | <u>oil mix #5</u> | <u>Infant formula</u> | <u>formula + mix #5</u> | <u>breast milk</u> |
|----|-------------------|-------------------|-----------------------|-------------------------|--------------------|
| 5  | 8:0 + 10:0        | 0.00              | 41.8                  | 40.78                   | 1.74               |
|    | 12:0 + 14:0       | 13.14             | 20.7                  | 20.52                   | 14.95              |
|    | 16:0              | 16.83             | 6.8                   | 7.04                    | 19.80              |
|    | 16:1              | 8.39              | 0.2                   | 0.40                    | 3.20               |
|    | 18:0              | 0.20              | 2.3                   | 2.25                    | 5.91               |
| 10 | 18:1              | 7.66              | 10.0                  | 9.94                    | 34.82              |
|    | 18:2 n6           | 6.97              | 17.4                  | 17.15                   | 16.00              |
|    | 18:3 n3           | 2.26              | 0.9                   | 0.93                    | 0.62               |
|    | 18:3 n6           | 0.25              | --                    | 0.01                    | 0.00               |
|    | 20:1              | 0.11              | 0.1                   | 0.10                    | 1.10               |
| 15 | 20:2 n6           | --                | --                    | 0.00                    | 0.61               |
|    | 20:3 n6           | --                | --                    | 0.00                    | 0.42               |
|    | 20:4 n6           | 23.72             | --                    | 0.58                    | 0.59               |
|    | 20:5 n3           | 1.11              | --                    | 0.03                    | 0.03               |
|    | 22:1              | --                | --                    | 0.00                    | 0.10               |
| 20 | 22:4 n6           | --                | --                    | 0.00                    | 0.21               |
|    | 22:5 n6           | 0.17              | --                    | 0.00                    | 0.22               |
|    | 22:6 n3           | 8.35              | --                    | 0.20                    | 0.19               |

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Example 10. Preparation of Oil Mix #6 and addition to  
infant formula

This mixture represents a totally vegetarian  
source of arachidonic and docosaheptaenoic acid. This  
5 supplement would be considered acceptable to persons  
restricted to a vegetarian diet. Sanders et al.  
(*American J. Clin. Nutr.* 31:805; 1978) have reported  
that the DHA levels in the breast milk of vegetarian  
mothers are depressed. Enteral supplementation of the  
10 blend will elevate the serum and hence breast milk  
levels of DHA to that of omnivorous mothers. This  
blend is prepared by mixing one part DHA oil (obtained  
from *Cryptothecodinium cohnii* as described in Example 3)  
with five parts ARA oil (obtained from *Mortierella*  
15 *alpina* as described in Example 2). The resulting  
mixture has the fatty acid composition shown in  
Table 7. This blend is mixed in a ratio of one part to  
thirty-five parts of the oils regularly in infant  
formula. At a normal fat content of 35 g fat per  
20 liter, this would correspond to the addition of 1 g per  
liter of prepared formula. This supplement provides  
ARA and DHA levels equivalent to human breast milk.

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in proportions of 1:5 by weight.

|    | <u>Fatty Acid</u> | <u>Oil Mix #6</u> | <u>Infant<br/>Formula</u> | <u>Formula +<br/>Mix #6</u> | <u>Breast<br/>Milk</u> |
|----|-------------------|-------------------|---------------------------|-----------------------------|------------------------|
| 5  | 8:0 + 10:0        | 0.0               | 41.8                      | 40.6                        | 1.74                   |
|    | 12:0 + 14:0       | 4.0               | 20.7                      | 20.2                        | 14.95                  |
|    | 16:0              | 16.8              | 6.8                       | 7.1                         | 19.82                  |
|    | 16:1              | 0.5               | 0.2                       | 0.2                         | 3.2                    |
|    | 18:0              | 11.0              | 2.3                       | 2.5                         | 5.91                   |
| 10 | 18:1              | 17.8              | 10.0                      | 10.0                        | 34.82                  |
|    | 18:2 n6           | 11.1              | 17.4                      | 17.2                        | 16.00                  |
|    | 18:3 n3           | 5.2               | 0.9                       | 0.9                         | 0.62                   |
|    | 18:3 n6           | 4.5               | ---                       | 0.1                         | 0.00                   |
|    | 20:1              | ---               | 0.1                       | 0.1                         | 1.10                   |
| 15 | 20:2 n6           | ---               | ---                       | 0.0                         | 0.61                   |
|    | 20:3 n6           | 6.0               | ---                       | 0.17                        | 0.42                   |
|    | 20:4 n6           | 20.1              | ---                       | 0.57                        | 0.59                   |
|    | 20:5 n3           | 0.1               | ---                       | 0.01                        | 0.03                   |
|    | 22:1              | ---               | ---                       | 0.00                        | 0.10                   |
| 20 | 22:4 n6           | 2.0               | ---                       | 0.06                        | 0.21                   |
|    | 22:5 n6           | ---               | ---                       | 0.00                        | 0.22                   |
|    | 22:6 n3           | 6.1               | ---                       | 0.18                        | 0.19                   |

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We claim:

1. A process for supplementing infant formula comprising:

(a) obtaining at least two different long chain polyunsaturated fatty acid-containing microbial oils from at least two different microbial sources, and

(b) adding said oils to said infant formula.

2. The process of claim 1, wherein said oils are selected from omega-3 and omega-6 fatty acids.

3. A process for altering the composition of infant formula, such that the relative amount of omega-3 and omega-6 polyunsaturated fatty acids in said formula is substantially similar to the amount of said polyunsaturated fatty acids contained in human breast milk which comprises:

(a) obtaining microbial oils containing said polyunsaturated fatty acids from at least two species of microbes,

(b) blending said oils together, and

(c) adding said blend of oils to said infant formula in an amount effective to provide said formula with amounts of said polyunsaturated fatty acids substantially similar to the amounts in human breast milk.

4. The process of claim 3, wherein said oils are ARASCO and DHASCO.

5. The process of claim 4, wherein said DHASCO is blended with said ARASCO in a ratio of from about 1 to about 5 parts DHASCO to about 2 to about 12 parts ARASCO by weight of said blend.

6. The process of claim 5, wherein the ratio of DHASCO to ARASCO comprises about 1:3.

7. The process of claim 4, wherein said genera are selected from fungi and microalgae.



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8. The process of claim 7, wherein said fungi comprise *Pythium* or *Mortierella*.
9. The process of claim 8, wherein said microalgae comprise *Crypthecodinium* sp.
10. The process of claim 7, wherein said fungi comprises *Pythium* or *Mortierella* and said microalgae comprises *Crypthecodinium*.
11. The process of claim 10, wherein said *Pythium* comprises *P. insidiosum*, said *Mortierella* comprises *M. alpina* and said *Crypthecodinium* comprises *C. cohnii*.
12. The process of claim 4, wherein said oil further comprises EPASCO.
13. The process of claim 12, wherein said genera are selected from fungi and microalgae.
14. The process of claim 13, wherein said fungi comprise *Pythium* or *Mortierella*.
15. The process of claim 13, wherein said microalgae comprise *Crypthecodinium* and *Nitzschia*.
16. The process of claim 13, wherein said fungi comprise *Pythium* and *Mortierella* and said microalgae comprises *Crypthecodinium* and *Nitzschia* sp.
17. The process of claim 16, wherein said *Pythium* comprises *P. insidiosum* and said *Crypthecodinium* comprises *C. cohnii* and said *Nitzschia* comprises *N. alba* and said *Mortierella* comprises *M. alpina*.
18. The process of claim 3, further comprising blending said microbial oils with fish oil prior to adding said blend to said infant formula.
19. The process of claim 18, wherein said fish oil comprises about 1 part and said microbial oils comprise from about 1 to about 15 parts by weight of said blend.
20. The process of claim 19, wherein said microbial oils are selected from DHASCO and ARASCO and



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the ratio of said oils comprises about one part fish oil to ten parts ARASCO to three parts DHASCO.

21. A process for making a supplement for infant formula, comprising:

(a) obtaining a DHA-containing microbial oil and

(b) blending said oil with a gamma linolenic acid-containing oil, thereby producing said supplement.

22. The process of claim 21, wherein said linolenic acid-containing oil comprises primrose, borage, or black currant seed oil.

23. The process of claim 21, wherein said linolenic acid containing-oil comprises a microbial oil.

24. The process of claim 23, further comprising obtaining said linolenic acid-containing oil from *Mucor javanicus* or *Mortierella isabellina*.

25. The process of claim 21, further comprising blending with said DHA-containing microbial oil and said linolenic acid-containing oil an EPA-containing oil.

26. The process of claim 25, wherein said EPA-containing oil comprises fish oil.

27. The process of claim 26, wherein said fish oil comprises about one part, said linolenic acid-containing oil comprises about 4 parts and said DHA-containing oil comprises about 1 part by weight of said blend.

28. The process of claim 26, wherein said fish oil comprises about one part, said linolenic acid-containing oil comprises about 4 parts and said DHA-containing oil comprises about 1 part by weight of said blend.



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29. A composition comprising a blend of at least two long-chain polyunsaturated fatty acid-containing microbial oils.

30. The composition of claim 29, wherein said oils are selected from ARASCO and DHASCO.

31. The composition of claim 30, wherein said DHASCO is blended with said ARASCO such that a ratio of from about 1 to about 5 parts DHA and about 2 to about 12 parts ARA by weight of said blend is obtained.

32. The composition of claim 31, wherein the ratio of DHA to ARA comprises about 1:3 respectively.

33. The composition of claim 30, wherein said oil further comprises EPASCO.

34. The composition of claim 29, wherein said composition further comprises fish oil.

35. The composition of claim 34, wherein said fish oil comprises about 1 part and said microbial oils comprise from about 1 to about 15 parts by weight of said blend.

36. A composition comprising a blend of a DHA-containing microbial oil and a gamma linolenic acid-containing oil.

37. The composition of claim 36, wherein said linolenic acid-containing oil comprises primrose, borage, or black currant seed oil.

38. The composition of claim 36, wherein said linolenic acid containing-oil is an oil obtained from a microbe.

39. The composition of claim 38, wherein said microbe comprises *Mucor javanicus* or *Mortierella isabellina*.

40. The composition of claim 36, further comprising an EPA-containing oil.



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41. The composition of claim 40, wherein said EPA-containing oil comprises fish oil.

42. The composition of claim 41, wherein said fish oil comprises about one part, said linolenic acid-containing oil comprises about 4 parts and said DHA-containing oil comprises about 1 part by weight of said blend.

43. Nutritional supplements comprising mixtures of polyunsaturated fatty acid-containing microbial oil.

44. Nutritional supplements comprising mixtures of DHASCO and a gamma linolenic acid-containing oil.

45. Nutritional supplements comprising mixtures of ARASCO and fish oils.

46. The supplement of claim 43, further comprising fish oil.

47. The supplement of claim 46, wherein said fish oil comprises about 1 part and said microbial oils comprise from about 1 to about 15 parts by weight of said supplement.

48. The supplement of claim 47, wherein said microbial oils comprise DHASCO and ARASCO and the ratio of said oils comprises about one part fish oil to ten parts ARASCO to three parts DHASCO.

49. The supplement of claim 43, wherein said mixture comprises ARASCO and DHASCO.

50. The supplement of claim 49, wherein said DHASCO is blended with said ARASCO in a ratio of from about 1 to about 5 parts DHA to about 2 to about 12 parts ARA by weight of said supplement.

51. The supplement of claim 50, wherein the ratio of DHA to ARA comprises about 1:3.

52. The supplement of claim 44, wherein said linolenic acid-containing oil comprises primrose, borage, or black currant seed oil.



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53. The supplement of claim 44, wherein said linolenic acid containing-oil is obtained from a microbe.

54. The supplement of claim 53, wherein said microbe comprises *Mucor javonicus* or *Mortierella isabellina*.

55. The supplement of claim 44, further comprising an EPA-containing oil.

56. The supplement of claim 55, wherein said EPA-containing oil comprises fish oil.

57. The supplement of claim 56, wherein said fish oil comprises about one part, said linolenic acid-containing oil comprises about 4 parts and said DHA-containing oil comprises about 1 part by weight of said blend.

58. The supplement of claim 43, wherein said supplement is a human nutritional supplement.

59. The supplement of claim 58, wherein said human is a baby.

60. The supplement of claim 58, wherein said human is a pregnant or nursing woman.

61. The composition of claim 29, wherein said composition comprises an additive for supplementing an infant formula.

62. The composition of claim 29, wherein said composition comprises a total parenteral nutritional formula.

63. The composition of claim 34, said composition comprising an additive for supplementing an infant formula.

64. The composition of claim 34, wherein said composition comprises a total parenteral nutritional formula.



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65. The composition of claim 36, wherein said composition comprises an additive for supplementing an infant formula.

66. The composition of claim 36, wherein said composition comprises a total parenteral nutritional formula.

67. The composition of claim 45, wherein said composition comprises an additive for supplementing an infant formula.



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