[0004] These high fortification rates may lead to increased production costs and potential complications in formulating the final product without providing additional consumer benefits. Furthermore, the over fortified formulations may overwhelm the digestive tract with non-soluble lipophilic compounds leading to indigestion.

[0005] Accordingly, there is a need for nutritional compositions for infants, toddlers, children and adults that provide necessary lipophilic compounds in a more stable soluble form.

SUMMARY OF THE INVENTION

[0006] In one aspect, a nutritional composition having at least one protein, at least one fat, and at least one lipophilic compound, the composition comprising:

an activated assembly comprising at least one hydrophobic protein having a grand average of hydropathicity index (GRAVY) value of -0.5 to 0, at least one combination of monoglycerides and diglycerides ("MDG") and at least one lipophilic compound,

wherein at least 1% of the total MDG in the nutritional composition remains in an aqueous phase after centrifugation at 100,000 x g for 1 hour at 20 °C.

[0006a] In another aspect, there is a provided nutritional composition comprising at least one protein and vitamin D, having improved bioavailability of vitamin D, wherein the nutritional composition comprises:

an activated assembly comprising a combination of monoglycerides and diglycerides ("MDG"), at least one hydrophobic protein having a grand average of hydropathicity index (GRAVY) value of -0.5 to 0, and vitamin D, wherein the vitamin D has improved bioavailability when administered to a subject.

[0006b] In another aspect, there is provided a nutritional composition having at least one protein, at least one fat, and at least one lipophilic compound, the composition comprising:

an activated assembly comprising at least one hydrophobic protein having a grand average of hydropathicity index (GRAVY) value of -0.5 to 0, at least one combination of monoglycerides and diglycerides ("MDG") and at least one lipophilic compound,

wherein at least 15% of the total lipophilic compound in the nutritional composition remains in an aqueous phase after centrifugation at 1,000 x g for 1 hour at 20 °C.

[0007] In another aspect, the disclosure may be directed to a nutritional composition having at least one protein, at least one fat, and at least one lipophilic compound, the composition comprising: an activated assembly comprising at least one hydrophobic protein,

at least one combination of monoglycerides and diglycerides ("MDG") and at least one lipophilic compound, wherein at least 1% of the total MDG in the nutritional composition remains in the aqueous phase after centrifugation at 100,000 x g for 1 hour at 20 °C, wherein the assembly is (i) water soluble; and (ii) has a size of 100 kD to 1000 kD.

[0008] In another aspect, the disclosure may be directed to a nutritional composition having at least one protein, at least one fat, and at least one lipophilic compound, the composition comprising: an activated assembly comprising at least one hydrophobic protein, at least one combination of monoglycerides and diglycerides ("MDG") and at least one lipophilic compound, wherein at least 1% of the total MDG in the nutritional composition remains in the aqueous phase after centrifugation at 100,000 x g for 1 hour at 20 °C, wherein the assembly is (i) water soluble; and (ii) has a size of 100 kD to 1000 kD, wherein MDG increases the concentration of protein of the assembly by at least 2% compared to a nutritional composition without MDG.

[0009] In another aspect, the disclosure may be directed to a nutritional composition having at least one protein, at least one fat, and at least one lipophilic compound, the

CLAIMS

What is claimed is:

1. A nutritional composition having at least one protein, at least one fat, and at least one lipophilic compound, the composition comprising:

an activated assembly comprising at least one hydrophobic protein having a grand average of hydropathicity index (GRAVY) value of -0.5 to 0, at least one combination of monoglycerides and diglycerides ("MDG") and at least one lipophilic compound,

wherein at least 1% of the total MDG in the nutritional composition remains in an aqueous phase after centrifugation at 100,000 x g for 1 hour at 20 °C.

2. The nutritional composition of claim 1, wherein the assembly is (i) water soluble wherein at least 5% of the assembly remains in an aqueous phase after centrifugation at 31,000 x g for at least 1 hour at 20 °C; and (ii) has a size of 60 kD to 1000 kD.

3. The nutritional composition of any of the preceding claims, wherein MDG increases the concentration of the hydrophobic protein in the assembly by at least 2% compared to a nutritional composition without MDG.

4. The nutritional composition of any of the preceding claims, wherein MDG increases the bound lipophilic compound of the assembly by at least 2% compared to a nutritional composition without MDG.

5. The nutritional composition of any of the preceding claims, wherein the lipophilic compound of the composition has at least a 15% improvement in bioavailability when administered to a subject, wherein the 15% improvement in bioavailability is measured by lymphatic absorption of the composition over a nutritional composition without MDG.

6. The nutritional composition of any of the preceding claims wherein the protein is intact protein, hydrolyzed protein or combinations thereof.

7. The nutritional composition of any of the preceding claims, wherein the assembly is stable for at least 12 months at 23 °C.

8. The nutritional composition of any of the preceding claims, wherein the assembly is stable for at least 24 months at room temperature.

9. The nutritional composition of any of the preceding claims, wherein the hydrophobic protein is β-lactoglobulin, bovine lactoferrin, γ_2-casein, β-casein, α-lactalbumin, or combinations thereof.

10. The nutritional composition of any of the preceding claims wherein the assembly has a size of 60 kD to 400 kD.

11. The nutritional composition of any the preceding claims wherein the lipophilic compound is a carotenoid, a lipid soluble vitamin, a lipophilic antioxidant or combinations thereof.

12. The nutritional composition of claim 11, wherein the lipophilic compound is lutein, vitamin A, vitamin D, vitamin E, vitamin K or combinations thereof.

13. The nutritional composition of any of the preceding claims wherein the fat is MDG, coconut oil, fractionated coconut oil, soy oil, corn oil, olive oil, safflower oil, high oleic coconut oil, fractionated coconut oil, soy oil, corn oil, olive oil, safflower oil, high oleic safflower oil, sunflower oil, high oleic sunflower oil, palm oil, palm kernel oil, palm olein, canola oil, marine

oils, cottonseed oil, flax seed oil, hemp seed oil, peanut oil, borage oil, algal oils, fungal oils, MCT oil (medium chain triglycerides) and combinations thereof.

14. The nutritional composition of any of the preceding claims comprising from about 145 mg/kg to about 890 mg/kg of MDG based on total weight of the composition.

15. The nutritional composition of any of the preceding claims comprising from about 145 mg/kg to about 600 mg/kg of MDG based on total weight of the composition.

16. The nutritional composition of any of the preceding claims comprising from about 1.0 μg/kg to about 7.0 g/kg of the lipophilic compound based on total weight of the composition.

17. The nutritional composition of any of the preceding claims comprising from about 147.4 mg/kg to about 589.6 mg/kg of MDG and about 1.12 mg/kg of the lipophilic compound based on total weight of the composition.

18. The nutritional composition of any preceding claims, wherein the ratio of MDG to lipophilic compound are selected from the group consisting of 12000:1, 11000:1, 10000:1, 9000:1, 8000:1, 7000:1, 6000:1, 5000:1, 4000:1, 3000:1, 2000:1, 1000:1, 900:1, 800:1, 700:1, 600:1, 500:1, 400:1, 300:1, 200:1, 100:1, 75:1, 50:1, 25:1, 20:1, 15:1, 14:1, 13:1, 12:1, 11:1, 10:1, 9:1, 8:1, 7:1, 6:1, 5:1, 4:1, 3:1, 2:1 and 1:1 (w/w).

19. The nutritional composition of any preceding claims, wherein the ratio of MDG to lipophilic compound comprises a ratio of from about 12000:1 to about 1:1 (w/w).

20. The nutritional composition of claim 18 or claim 19, wherein the ratio of MDG to lipophilic compound is 4:1, 3:1 or 2:1.

21. The nutritional composition of any of the preceding claims comprising from about 1.0 g/L to about 100 g/L of hydrophobic protein based on total weight of the composition.

22. The nutritional composition of any of the preceding claims further comprising choline.

23. The nutritional composition of claim 22, comprising about 5 mg/kg to about 1 g/kg of choline based on total weight of the composition.

24. The nutritional composition of any of the preceding claims further comprising lecithin.

25. The nutritional composition of claim 24, comprising about 10 mg/kg to about 5 g/kg of lecithin based on total weight of the composition.

26. The nutritional composition of any of the preceding claims further comprising docosahexaenoic acid ("DHA").

27. The nutritional composition of claim 26, wherein the nutritional composition comprises about 10 mg/kg to about 10 g/kg DHA based on total weight of the composition.

28. The nutritional composition of any of the preceding claims further comprising high palmitic acid vegetable oil.

29. The nutritional composition of claim 28, wherein the nutritional composition comprises about 0.5 g/kg to about 35 g/kg of high palmitic acid vegetable oil based on total weight of the composition.

30. The nutritional composition of any of the preceding claims, wherein the nutritional composition comprises from about 0.2 g/L to about 20 g/L of β-casein based on total weight of the composition.

31. The nutritional composition of any of the preceding claims, wherein the nutritional composition comprises a carbohydrate.

32. The nutritional composition of claim 31, wherein the carbohydrate is maltodextrin, hydrolyzed or modified starch, hydrolyzed or modified cornstarch, glucose polymers, corn syrup, corn syrup solids, rice-derived carbohydrates, glucose, fructose, lactose, high fructose corn syrup, honey, sugar alcohols, maltitol, erythritol, sorbitol, or combinations thereof.

33. A nutritional composition comprising at least one protein and vitamin D, having improved bioavailability of vitamin D, wherein the nutritional composition comprises:

an activated assembly comprising a combination of monoglycerides and diglycerides ("MDG"), at least one hydrophobic protein having a grand average of hydropathicity index (GRAVY) value of -0.5 to 0, and vitamin D, wherein the vitamin D has improved bioavailability when administered to a subject.

34. The nutritional composition of claim 33, comprising from about 0.1 mg/kg to about 20 mg/kg of MDG based on total weight of the composition.

35. The nutritional composition of claim 34, comprising from about 0.1 mg/kg to about 10 mg/kg of MDG based on total weight of the composition.

36. The nutritional composition of claims 33-35 comprising from about 10 μg/kg to about 30 μg/kg of vitamin D based on total weight of the composition.

37. The nutritional composition of any one of claims 33-36 comprising from about 0.1 mg/kg to about 10 mg/kg of MDG and about 20 μg/kg of vitamin D based on total weight of the composition.

38. A nutritional composition having at least one protein, at least one fat, and at least one lipophilic compound, the composition comprising:

an activated assembly comprising at least one hydrophobic protein having a grand average of hydropathicity index (GRAVY) value of -0.5 to 0, at least one combination of monoglycerides and diglycerides ("MDG") and at least one lipophilic compound,

wherein at least 15% of the total lipophilic compound in the nutritional composition remains in an aqueous phase after centrifugation at 1,000 x g for 1 hour at 20 °C.