pressure between 1500 and 4500 psig. The slurry is then typically evaporated to about 45% to 60% total solids and spray dried. This generally produces stable fat that is not subject to substantial oxidation during storage and is easily reconstituted.

[0006] Although extruders and related methods are known as highly efficient methods that significantly minimize the amount of water and energy needed and that are capable of producing pellets or cake that can be dried and ground into powdered material, extruders using conventional processing elements and related methods have generally not been used to date to prepare the emulsion required to produce powdered nutritional products because existing extruders and related methods are not generally known to consistently produce a finished powdered nutritional product with a fat emulsion that is sufficiently stable for commercial purposes without utilizing additional equipment to prepare the emulsion external to the extruder. Extruders using conventional processing elements and related methods are not generally known to be able to adequately emulsify the fat required by powdered nutritional products within the extruder itself. Without proper emulsification of the fat globules prior to extrusion, the fat is subject to oxidation and rancidity during storage and fat separation during reconstitution.

[0007] While a variety of extruders and related methods have been made and used, it is believed that no one prior to the inventors has made or used an invention as described herein.

Summary

[0008] A method of producing an emulsion and an extrudate for a powdered nutritional product within an extruder is disclosed. The method for producing an emulsion includes the steps of: a) providing an extruder, wherein the extruder includes i) a barrel, and ii) a high shear element (32) positioned within the barrel (20), wherein the high shear element (32) comprises at least one circular shearing disc (650a); b) delivering a first portion of ingredients to the high shear element; and c) emulsifying the first portion of ingredients by processing the first portion ingredients through the high shear element to produce an emulsion, wherein, prior to emulsification, the first portion of ingredients comprises a slurry. The method for producing an extrudate further includes the steps of: d) delivering a second portion of ingredients into the barrel via a feeder for the second portion of ingredients; e) combining the emulsion and the second portion of ingredients to form an extrudate; and f) processing the extrudate through the extruding section.

[0008a] Also provided is a method of producing an extrudate for a powdered nutritional product comprising the steps of:

a) providing an extruder comprising

i) a barrel,

ii) a first feeder in communication with the barrel,

What is claimed is:

1) A method of producing an emulsion for a powdered nutritional product within an extruder comprising the steps of:

   a) providing an extruder (10) comprising

      i) a barrel (20), and

      ii) a high shear element (32) positioned within the barrel (20), wherein the high shear element (32) comprises at least one circular shearing disc (650a);

   b) delivering a first portion of ingredients to the high shear element (32); and

   c) emulsifying the first portion of ingredients by processing the first portion of ingredients through the high shear element (32) to produce an emulsion, wherein, prior to emulsification, the first portion of ingredients comprises a slurry.

2) The method of claim 1, wherein the high shear element (32) emulsifies the slurry by subjecting at least a portion of the slurry to a shear rate between 30 sec^{-1} and 2,500 sec^{-1}.

3) The method of claim 2, wherein the high shear element (32) emulsifies the slurry by subjecting at least a portion of the slurry to a shear rate of at least 100 sec^{-1}.

4) The method of claim 1, wherein the first portion of ingredients comprises a protein content that is less than a total amount of protein required to produce the powdered nutritional product, but is sufficient to emulsify any fat contained in the first portion of ingredients.

5) The method of claim 1, wherein the first portion of ingredients further comprises:

   a) a fat content that is 100% of an amount of fat required to produce the powdered nutritional product; and

   b) a water content that is 100% of an amount of water required to produce the powdered nutritional product.

6) The method of claim 1, wherein the extruder (10) comprises a twin screw extruder (210) comprising a first central shaft (680a) and a second central shaft (680b).

7) The method of claim 6, wherein the high shear element (32) comprises a first circular shearing disc (650a) mounted on the first central shaft (680a) and a second circular shearing disc (650b) mounted on the second central shaft (680b).

8) The method of claim 7, wherein the extruder (210) further comprises a second high shear element (32) positioned within the barrel (20), wherein the second high shear element (32) comprises a third circular shearing disc (650a) mounted on the first central shaft (680a) and a fourth circular shearing disc (650b) mounted on the second central shaft (680b).

9) A method of producing an extrudate for a powdered nutritional product comprising the steps of:

a) providing an extruder (10) comprising

i) a barrel (20),

ii) a first feeder (22) in communication with the barrel (20),

iii) a second feeder (24) in communication with the barrel (20) and positioned downstream relative to the first feeder (22),

iv) at least one central shaft (680a) positioned within the barrel (20),

v) an emulsifying section (31) positioned between the first feeder (22) and the second feeder (24), wherein the emulsifying section (31) comprises a rotating high shear element (32) engaged with the at least one central shaft (680a),

vi) a mixing section (30) positioned upstream relative to the emulsifying section (31), and

vii) an extruding section (34) positioned downstream relative to the emulsifying section (31);

b) delivering a first portion of ingredients into the barrel (20) via the first feeder (22);

c) processing the first portion of ingredients through the mixing section (30) to produce a slurry;

d) processing the slurry through the emulsifying section (31) to produce an emulsion;

e) delivering a second portion of ingredients into the barrel (20) via the second feeder (24);

f) combining the emulsion and the second portion of ingredients to form an extrudate; and

g) processing the extrudate through the extruding section (34).

10) The method of claim 9, wherein the emulsifying section (31) further comprises at least one processing element engaged with the at least one central shaft (680a).

11) The method of claim 9wherein step (d) is accomplished by rotating the at least one central shaft (680a) and the rotating high shear element (32) at a speed between 100 RPM and 1100 RPM.

12) The method of claim 9, wherein the extruder (10) further comprises an ultrasonic unit positioned upstream relative to the extruding section (34).

13) The method of claim 9, wherein the rotating high shear element (32) comprises a first shearing disc (650a) mounted onto the at least one central shaft (680a), wherein the first shearing disc (650a) comprises:

a) a central hub (660a) comprising a central opening (662a); and

b) an outer lip (670a) that extends radially around the central hub (660a) and comprises an axial length and an outer edge.

14) The method of claim 13, wherein the outer lip (670a) further comprises a plurality of openings (672a) that extend through the outer lip (670a) along the axial length of the outer lip (670a).

15) The method of claim 13, wherein the outer lip (670a) further comprises a plurality of indentations along at least a portion of the outer edge of the outer lip (670a).

16) A method of producing an extrudate for a powdered nutritional product comprising the steps of:

a) providing a twin screw extruder (210) comprising

i) a barrel (220),

ii) a first central shaft (680a) positioned within the barrel (220),

iii) a second central shaft (680b) positioned within the barrel (220),

iv) a first shearing disc (650a) mounted on the first central shaft (680a),

v) a second shearing disc (650b) mounted on the second central shaft (680b), wherein the second shearing disc (650b) is positioned substantially adjacent to the first shearing disc (650a), and

vi) an extruding section (234) positioned within the barrel (220), wherein the extruding section (234) is positioned downstream relative to the first shearing disc (650a) and the second shearing disc (650b);

b) emulsifying a first portion of ingredients by processing the first portion of ingredients through the first shearing disc (650a) and the second shearing disc (650b) to produce an emulsion, wherein, prior to emulsification, the first portion of ingredients comprises a slurry;

c) delivering the emulsion and a second portion of ingredients to the extruding section (234); and

d) extruding the emulsion together with the second portion of ingredients in the extruding section (234).

17) The method of claim 16, wherein the second portion of ingredients comprises substantially all ingredients required to produce the powdered nutritional product not included in the first portion of ingredients.

18) The method of claim 1 or 16, wherein the slurry is produced outside the extruder (10, 210).

What is claimed is:

1) A method of producing an emulsion for a powdered nutritional product within an extruder comprising the steps of:

a) providing an extruder comprising

i) a barrel, and

ii) a high shear element positioned within the barrel;

b) delivering a first portion of ingredients to the high shear element; and

c) emulsifying the first portion of ingredients by processing the first portion of ingredients through the high shear element to produce an emulsion, wherein, prior to emulsification, the first portion of ingredients comprises a slurry.

2) The method of claim 1, wherein the high shear element emulsifies the slurry by subjecting at least a portion of the slurry to a shear rate between 30 sec^{-1} and 2,500 sec^{-1}.

3) The method of claim 2, wherein the high shear element emulsifies the slurry by subjecting at least a portion of the slurry to a shear rate of at least 100 sec^{-1}.

4) The method of claim 1, wherein the first portion of ingredients comprises a protein content that is less than a total amount of protein required to produce the powdered nutritional product, but is sufficient to emulsify any fat contained in the first portion of ingredients.

5) The method of claim 1, wherein the first portion of ingredients further comprises:

a) a fat content that is 100% of an amount of fat required to produce the powdered nutritional product; and

b) a water content that is 100% of an amount of water required to produce the powdered nutritional product.

6) The method of claim 1, wherein the high shear element comprises at least one shearing disc.

7) The method of claim 1, wherein the extruder comprises a twin screw extruder comprising a first central shaft and a second central shaft.

8) The method of claim 7, wherein the high shear element comprises a first shearing disc mounted on the first central shaft and a second shearing disc mounted on the second central shaft.

9) The method of claim 8, wherein the extruder further comprises a second high shear element positioned within the barrel, wherein the second high shear element comprises a third shearing disc mounted on the first central shaft and a fourth shearing disc mounted on the second central shaft.

10) A method of producing an extrudate for a powdered nutritional product comprising the steps of:

a) providing an extruder comprising

i) a barrel,

ii) a first feeder in communication with the barrel,

iii) a second feeder in communication with the barrel and positioned downstream relative to the first feeder,

iv) at least one central shaft positioned within the barrel,

v) an emulsifying section positioned between the first feeder and the second feeder, wherein the emulsifying section comprises a rotating high shear element engaged with the at least one central shaft,

vi) a mixing section positioned upstream relative to the emulsifying section, and

vii) an extruding section positioned downstream relative to the emulsifying section;

b) delivering a first portion of ingredients into the barrel via the first feeder;

c) processing the first portion of ingredients through the mixing section to produce a slurry;

d) processing the slurry through the emulsifying section to produce an emulsion;

e) delivering a second portion of ingredients into the barrel via the second feeder;

f) combining the emulsion and the second portion of ingredients to form an extrudate; and

g) processing the extrudate through the extruding section.

11) The method of claim 10, wherein the emulsifying section further comprises at least one processing element engaged with the at least one central shaft.

12) The method of claim 10 wherein step (d) is accomplished by rotating the at least one central shaft and the rotating high shear element at a speed between 100 RPM and 1100 RPM.

13) The method of claim 10, wherein the extruder further comprises an ultrasonic unit positioned upstream relative to the extruding section.

14) The method of claim 10, wherein the rotating high shear element comprises a first shearing disc mounted onto the at least one central shaft, wherein the first shearing disc comprises

a) a central hub comprising a central opening; and

b) an outer lip that extends radially around the central hub and comprises an axial length and an outer edge.

15) The method of claim 14, wherein the outer lip further comprises a plurality of openings that extend through the outer lip along the axial length of the outer lip.

16) The method of claim 14, wherein the outer lip further comprises a plurality of indentations along at least a portion of the outer edge of the outer lip.

17)A method of producing an extrudate for a powdered nutritional product comprising the steps of:

a) providing a twin screw extruder comprising

i) a barrel,

ii) a first central shaft positioned within the barrel,

iii) a second central shaft positioned within the barrel,

iv) a first shearing disc mounted on the first central shaft,

v) a second shearing disc mounted on the second central shaft, wherein the second shearing disc is positioned substantially adjacent to the first shearing disc, and

vi) an extruding section positioned within the barrel, wherein the extruding section is positioned downstream relative to the first shearing disc and the second shearing disc;

b) emulsifying a first portion of ingredients by processing the first portion of ingredients through the first shearing disc and the second shearing disc to produce an emulsion, wherein, prior to emulsification, the first portion of ingredients comprises a slurry;

c) delivering the emulsion and a second portion of ingredients to the extruding section; and

d) extruding the emulsion together with the second portion of ingredients in the extruding section.

18) The method of claim 17, wherein the second portion of ingredients comprises substantially all ingredients required to produce the powdered nutritional product not included in the first portion of ingredients.

19) The method of claim 1 or 17, wherein the slurry is produced outside the extruder.