

Binder system for a meat analogue product

Background

Almost all commercially available vegetarian and vegan meat analogue food products currently use methylcellulose alone or combined with other additives for achieving optimal binding properties.

Methylcellulose (MC) is the simplest cellulose derivative. Methyl groups ($-CH_3$) replace the naturally occurring hydroxyls at the C-2, C-3 and/or C-6 positions of the cellulose anhydro-D-glucose units. Typically, commercial MC is produced via alkaline treatment (NaOH) for swelling cellulosic fibres to form an alkali-cellulose which would then react with an etherifying agent such as chloromethane, iodomethane or dimethyl sulfate. Acetone, toluene, or isopropanol can also sometimes be added, after the etherifying agent, for tailoring the final degree of methylation. As a result, MC has amphiphilic properties and exhibits a unique thermal behavior which is not found in naturally occurring polysaccharide structures i.e. it gels upon heating.

Gelation is a two step process in which a first step is mainly driven by hydrophobic interactions between highly methylated residues, and then a second step which is a phase separation occurring at $T > 60^\circ C$ with formation of a turbid strong solid-like material. This gelation behavior upon heating of MC is responsible for the unique performance in plant based burgers when shape retention is required upon cooking. It is similar to the performance of an egg white binder.

However, consumers are becoming increasingly concerned about undesirable chemically modified ingredients in their products. Existing solutions for replacing MC involve the use of other additives in combination with other ingredients for achieving desired functionality. Some of those additives also undergo chemical modification during manufacturing to achieve desired functionality.

Carbohydrate based binders can be based on calcium-alginate gels. In order to achieve gelation, a slow acid release (from either glucono-delta-lactone, citric acid, lactic acid) is needed to liberate calcium ions for crosslinking with alginate to form the gel. This process is rather complex to use in application and the functionality is limited to strong, firm gels hence applicable only for specific meat analogues (e.g. sausages).

The use of starch-based binders has a detrimental effect on texture, leading to products with a mushy sensory perception which also crumbles when it is cooked. In addition, starches and flours are high glycemic carbohydrates, which might be not desired or recommended for specific consumer populations (e.g. diabetics or those wishing to limit carbohydrate content).

All of the following meat analogues comprise an additive as part of the binding agent solution.

In EP 1 759 593 A1, a minced meat analogue is described containing proteins combined with fibres and and 10 wt.% of alginate, pectin and combinations.

- 5 In US 2005/0008758A1, the binder comprises hydrogenated fat, water, and a component selected from the group consisting of methylcellulose, modified cornstarch, and a combination thereof.

WO 2016/120594 describes an edible vegan formulation comprising fungal particles, potentially strengthened by presence of calcium ions, hydrocolloids, gluten or a non-wheat based vegetable protein.

- 10 Due to all those deficiencies, there are nowadays no plant-based meat analogues that are acceptable for consumers in terms of optimal textural attributes and a more label-friendly, natural ingredient list.

There is a clear need for a plant-based, label-friendly, natural binder as an analogue to MC with enhanced functional properties.

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Summary of invention

The present invention relates to meat analogue products having a plant based, clean label, natural binder as a substitute for methylcellulose and its derivatives (e.g. hydroxypropyl-methylcellulose) in food applications.

- 20 The inventors of the present application have surprisingly found a binder which has similar functional properties to methylcellulose. The functional properties refer to binding the meat analogue product in cold or room temperature conditions (prior to cooking), hence enabling optimal molding and shape retention during storage. Moreover, the binder exhibits a sequential gelling mechanism as function of temperature: a heat-set gelling process occurs on
25 heating to cooking temperature, followed by a cold-set gelling process that takes place on cooling to consumption temperature. This prevents crumbling of the meat analogue during cooking while providing a firm, 'meaty' bite during consumption.

The texture of the product is improved versus alternative binders such as hydrocolloids (e.g. alginate, agar, konjac gum) which tend to give gummy mouthfeel.

Moreover, the binder does not exhibit water leakage during storage of the meat analogue product in the cold when compared to burgers with binders comprising methylcellulose or other additives.

Embodiments of the invention

- 5 The present invention relates to the field of meat analogues for human consumption.

The present invention relates to a method of making a meat analogue, said method comprising mixing a cold set gelling dietary fibre, preferably psyllium fibre.

- 10 The present invention further relates to a method of making a meat analogue, said method comprising mixing a cold set gelling dietary fibre, preferably psyllium fibre; a heat-set gelling plant based ingredient, preferably flour; optionally calcium salt; lipid; plant extract; optionally solid fat; and water.

The invention further relates to a method of making a meat analogue, said method comprising

- 15 a. Mixing in water a cold set gelling dietary fibre, preferably psyllium fibre; a heat-set gelling plant based ingredient, preferably flour; and optionally calcium salt to form a binder aqueous phase;
- b. Adding lipid to the binder aqueous phase and homogenizing to form an emulsion gel binder;
- c. Mixing plant extract with the emulsion gel binder, optionally adding solid fat, and optionally molding, to form a meat analogue.

- 20 The binder aqueous phase may be formed by mixing at 1000 rpm or greater, preferably about 8000 rpm or greater.

The emulsion gel binder may be formed by homogenizing at 2000 rpm or greater, preferably about 8000 rpm or greater.

An additional cooling step and mixing step may be performed before adding the solid fat.

- 25 Preferably, the meat analogue is devoid or substantially devoid of additives.

The meat analogue may comprise 20 to 85 wt.%, or 20 to 75 wt.% emulsion gel binder.

The plant extract may be a plant protein.

The plant extract may be a high moisture extruded (HME) plant extract and/or a textured vegetable protein (TVP) plant extract.

- 5 Preferably, when the plant extract is a HME plant extract, the meat analogue comprises 20 to 60 wt. %, or about 50 wt. % emulsion gel binder. Preferably, when the plant extract is a TVP plant extract, the meat analogue comprises 55 to 75 wt. %, or about 55 to 85 wt.%, or about 65 wt. % emulsion gel binder.

The emulsion gel binder may comprise 0.5 to 20 wt.% cold set gelling dietary fibre, preferably 1 to 10 wt.% cold set gelling dietary fibre, more preferably 1 to 5 wt.% cold set gelling dietary fibre.

- 10 Preferably, when the plant extract is a TVP plant extract, the emulsion gel binder comprises about 2.2 wt.% cold set gelling dietary fibre. Preferably, when the plant extract is a HME plant extract, the emulsion gel binder comprises about 3.6 wt.% cold set gelling dietary fibre.

The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 20°C may exhibit a shear thinning behavior with zero shear rate viscosity above 100 Pa.s.

- 15 The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 7°C may exhibit a G' (storage modulus) greater than 40 Pa and G'' (loss modulus) lower than 150Pa at 1Hz frequency and a strain of 0.2%.

- 20 The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 60°C may exhibit a G' (storage modulus) greater than 4 Pa and G'' (loss modulus) lower than 45Pa at 1Hz frequency and a strain of 0.2%.

The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 20°C may exhibit a G' (storage modulus) greater than 30 Pa and G'' (loss modulus) lower than 50Pa at 1Hz frequency and a strain of 0.2%.

- 25 Preferably, the cold set gelling dietary fibre has a soluble fraction of greater than 50 wt.%, for example between 50 wt.% to 90 wt.%, for example about 70 wt.%.

- 30 The cold set gelling dietary fibre may be derived from tubers, for example potato, cassava, yam, or sweet potato, or from vegetables, for example carrot, pumpkin, or squash, or from fruit, for example citrus fruit, or from legumes, for example pulses, or from oilseeds, for example flaxseed, or from psyllium, chia seeds, potato, apple, fenugreek, chickpea, carrot, oat, or citrus fruit.

Preferably, the cold set gelling dietary fibre is derived from psyllium, potato, citrus, or fenugreek. The cold set gelling dietary fibre may comprise psyllium fibre in combination with

at least one other fibre, for example citrus fibre, wherein the cold set gelling dietary fibre comprises at least 50% psyllium fibre. The citrus fibre may have a soluble fraction greater than 30%, preferably a soluble fraction greater than 40%. Preferably, the cold set gelling dietary fibre is or comprises psyllium fibre.

- 5 Preferably, the emulsion gel binder comprises between 1 to 20 wt.% heat-set gelling plant based ingredient or combination of ingredients.

Preferably, when the plant extract is TVP plant extract, the emulsion gel binder comprises about 2.7 wt.% heat-set gelling plant based ingredient. Preferably, when the plant extract is HME plant extract, the emulsion gel binder comprises about 10.7 wt.% plant based heat-set
10 gelling plant based ingredient.

The heat-set gelling plant based ingredient preferably exhibits a G' (storage modulus) greater than 130 Pa and G'' (loss modulus) lower than 85 Pa at 1Hz frequency and a strain of 0.2% at 10 wt. % in an aqueous solution at 60°C, after heating to 90°C.

- 15 The heat-set gelling plant based ingredient preferably exhibits a G' (storage modulus) greater than 130 Pa and G'' (loss modulus) lower than 60 Pa at 1Hz frequency and a strain of 0.2% at 10 wt. % in an aqueous solution at 60°C, after heating to 90°C.

The heat-set gelling plant based ingredient comprises starch, and/or protein, preferably a combination of starch and protein, for example between 5 to 95 wt.% starch and 5 to 95 wt.% protein.

- 20 The heat-set gelling plant based ingredient may comprise between 60 to 80 wt.% starch and 10 to 20 wt.% protein

For example, the heat-set gelling plant based ingredient may comprise about 70 wt.% starch and about 14 wt.% protein.

- 25 The heat-set gelling plant based ingredient may be, for example, quinoa flour, rice flour, buckwheat flour, wheat flour, chickpea flour, pumpkin seed flour, soy flour, chia flour, lentils flour, sesame flour, or combinations of these. Preferably, the heat-set gelling plant based ingredient is quinoa flour or rice flour, most preferably quinoa flour. Preferably, the plant protein isolate or concentrate is, for example, from soy, faba bean, potato, quinoa, pea, canola, rubisco, mung bean, chickpea, hemp, seaweed, lentils, buckwheat. Preferably, the
30 plant protein or concentrate is from soy, faba bean, potato, chia, or quinoa.

The heat-set gelling plant based ingredient may be quinoa flour and soy protein isolate, or rice flour and soy protein isolate.

Preferably, the emulsion gel binder comprises (i) heat-set gelling plant based ingredient, and (ii) cold set gelling dietary fibre in a ratio ranging from between 9:1 to 4:6, preferably between 8:2 and 6:4. Preferably, when the plant extract is HME plant extract, the ratio is about 8:2. Preferably, when the plant extract is TVP plant extract, the ratio is about 5:5. Preferably, when the plant extract is HME plant extract, the ratio is about 7:3.

Preferably, the emulsion gel binder exhibits a G' greater than 20 Pa and a G'' lower than 240 Pa upon heating until 90°C and a G' greater than 100 Pa and a G'' lower than 300 Pa upon subsequent cooling until 60°C, at 1Hz frequency and a strain of 0.2%.

The lipid may be from any plant source. For example the lipid may be canola oil, sunflower oil, olive oil, or coconut oil. Preferably, the lipid is canola oil and/or coconut oil, or mixtures thereof.

Preferably, the emulsion gel binder comprises calcium salt, for example 0.1 to 10 wt.% calcium salt, more preferably 0.5 to 1.5 wt. % calcium salt.

The emulsion gel binder may further comprise vinegar, preferably between 1 to 10 wt.% vinegar.

The meat analogue may comprise 15 to 90 wt.%, or 15 to 75 wt.% plant extract, preferably 25 to 70 wt.% plant extract. Preferably, for a meat analogue comprising TVP plant extract, the meat analogue comprises 20 to 40 wt.%, or 25 to 40 wt.%, or about 32 wt.% TVP plant extract. Preferably, for a meat analogue comprising HME plant extract, the meat analogue comprises 45 to 80 wt. %, or 45 to 70 wt.%, or about 50 to 65 wt% HME plant extract.

The plant extract may be derived from legumes, cereals, fruits, or oilseeds. For example, the plant extract may be derived from soy, pea, wheat, faba bean, chickpea, lentils, citrus fruits, or sunflower.

Preferably, the plant extract is soy protein, pea protein, chickpea protein, faba bean protein, sunflower protein, wheat gluten, and combinations of these.

Preferably, the plant extract is gluten and/or textured vegetable protein, for example textured soy protein, textured pea protein, textured chickpea protein, textured faba bean protein, textured lentil protein, textured sunflower protein, and/or combinations of these. More preferably, the plant extract is textured soy protein and/or textured pea protein.

The plant extract may be made by extrusion to make a textured protein.

The optional solid fat may be derived from coconut, shea nut, palm, mango. For example, the optional solid fat may be derived from coconut, for example coconut flakes.

The meat analogue may be minced meat or ground meat or molded to form a burger, meatball, sausage, or cold cut. Preferably, the meat analogue is a burger.

The meat analogue can be cooked, for example deep fried, pan fried, microwaved, oven baked, and combinations of these. The meat analogue can be stored frozen prior or after
5 cooking.

The meat analogue can be packaged, for example in a modified atmosphere.

Preferably, the invention relates to a method of making a vegan meat analogue, said method comprising

- 10 a. Mixing in water a cold set gelling dietary fibre, preferably psyllium fibre; a heat-set gelling plant based ingredient, preferably flour; and optionally calcium salt to form a binder aqueous phase;
- b. Adding lipid to the binder aqueous phase and homogenizing to form an emulsion gel binder;
- 15 c. Mixing plant extract with the emulsion gel binder, optionally adding solid fat, and optionally molding, to form a meat analogue.

The invention further relates to a meat analogue comprising water, plant extract, lipid, heat-set gelling plant based ingredient, and cold set gelling dietary fibre.

The invention further relates to a meat analogue comprising plant extract; optional solid fat; and an emulsion gel binder comprising water, lipid, heat-set gelling plant based ingredient,
20 and cold set gelling dietary fibre.

The invention further relates to a meat analogue, comprising

- a. Plant extract;
- b. Optional solid fat; and
- 25 c. Emulsion gel binder comprising
 - i. Cold set gelling dietary fibre, preferably psyllium fibre;
 - ii. Heat-set gelling plant based ingredient, preferably flour;
 - iii. Lipid;
 - iv. Water; and
 - v. optional calcium salt.

30 Preferably, the meat analogue is devoid or substantially devoid of additives.

The meat analogue may comprise 15 to 85 wt.%, or 20 to 75 wt.% emulsion gel binder.

Preferably, the meat analogue comprises 20 to 85 wt%, or 20 to 75 wt% emulsion gel binder, wherein the emulsion gel binder comprises 1.5 to 20 wt.% cold set gelling dietary fibre, and 1.5 to 20 wt.% heat-set gelling plant based ingredient.

- 5 Preferably, the meat analogue comprises 0.225 to 17 wt% cold set gelling dietary fibre and 0.225 to 17 wt% heat set gelling plant based ingredient.

Preferably, the meat analogue comprises 15 to 85 wt.%, or 20 to 75 wt.% plant extract; 1 to 5 wt.% cold set gelling dietary fibre; and 1 to 5 wt.% heat-set gelling plant based ingredient.

- 10 The plant extract may be a high moisture extruded (HME) plant extract and/or a textured vegetable protein (TVP) plant extract. Preferably, the HME plant extract has a moisture content between 40 to 70 wt.%, more preferably about 60 wt.%. Preferably, the TVP plant extract is in a dry form. Preferably, the moisture content is less than 5 wt.%.

- 15 Preferably, when the plant extract is a HME plant extract, the meat analogue comprises 20 to 55 wt. %, or about 50 wt. % emulsion gel binder. Preferably, when the plant extract is a TVP plant extract, the meat analogue comprises 55 to 75 wt. %, or about 65 wt. % emulsion gel binder.

The emulsion gel binder may comprise 0.5 to 20 wt.% cold set gelling dietary fibre, preferably 1 to 10 wt.% cold set gelling dietary fibre, more preferably 1 to 5 wt.% cold set gelling dietary fibre.

- 20 Preferably, when the plant extract is a TVP plant extract, the emulsion gel binder comprises about 2.2 wt.% cold set gelling dietary fibre. Preferably, when the plant extract is a HME plant extract, the emulsion gel binder comprises about 3.6 wt.% cold set gelling dietary fibre.

The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 20°C may exhibit a shear thinning behavior with zero shear rate viscosity above 100 Pa.s.

- 25 The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 7°C may exhibit a G' (storage modulus) greater than 40 Pa and G'' (loss modulus) lower than 150Pa at 1Hz frequency and a strain of 0.2%.

- 30 The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 60°C may exhibit a G' (storage modulus) greater than 4 Pa and G'' (loss modulus) lower than 45Pa at 1Hz frequency and a strain of 0.2%.

The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 20°C may exhibit a G' (storage modulus) greater than 30 Pa and G'' (loss modulus) lower than 50Pa at 1Hz frequency and a strain of 0.2%.

5 Preferably, the cold set gelling dietary fibre has a soluble fraction of greater than 50 wt.%, for example between 50 wt.% to 90 wt.%, for example about 70 wt.%.

10 The cold set gelling dietary fibre may be derived from tubers, for example potato, cassava, yam, or sweet potato, or from vegetables, for example carrot, pumpkin, or squash, or from fruit, for example citrus fruit, or from legumes, for example pulses, or from oilseeds, for example flaxseed, or from psyllium, chia seeds, potato, apple, fenugreek, chickpea, carrot, oat, or citrus fruit.

15 Preferably, the cold set gelling dietary fibre is derived from psyllium, potato, citrus, or fenugreek. The cold set gelling dietary fibre may comprise psyllium fibre in combination with at least one other fibre, for example citrus fibre, wherein the cold set gelling dietary fibre comprises at least 50% psyllium fibre. The citrus fibre may have a soluble fraction greater than 30%, preferably a soluble fraction greater than 40%. Preferably, the cold set gelling dietary fibre is or comprises psyllium fibre.

Preferably, the emulsion gel binder comprises between 1 to 20 wt.% heat-set gelling plant based ingredient.

20 Preferably, when the plant extract is TVP plant extract, the emulsion gel binder comprises about 2.7 wt.% heat-set gelling plant based ingredient. Preferably, when the plant extract is HME plant extract, the emulsion gel binder comprises about 10.7 wt.% plant based heat-set gelling plant based ingredient.

25 The plant based heat-set gelling ingredient preferably exhibits a G' (storage modulus) greater than 130 Pa and G'' (loss modulus) lower than 60 Pa at 1Hz frequency and a strain of 0.2% at 10 wt. % in an aqueous solution at 60°C, after heating to 90°C.

The heat-set gelling plant based ingredient comprises starch, and/or protein, preferably a combination of starch and protein, for example between 5 to 95 wt.% starch and 5 to 95 wt.% protein.

30 The heat-set gelling plant based ingredient may comprise between 60 to 80 wt.% starch and 10 to 20 wt.% protein

For example, the heat-set gelling plant based ingredient may comprise about 70 wt.% starch and about 14 wt.% protein.

The heat-set gelling plant based ingredient may be, for example, quinoa flour, rice flour, buckwheat flour, wheat flour, chickpea flour, pumpkin seed flour, sesame flour, soy flour, chia flour, or combinations of these. Preferably, the heat-set gelling plant based ingredient is quinoa flour or rice flour, most preferably quinoa flour.

- 5 Preferably, the emulsion gel binder comprises (i) heat-set gelling plant based ingredient, and (ii) cold set gelling dietary fibre in a ratio ranging from between 9:1 to 4:6, preferably between 8:2 and 6:4. Preferably, when the plant extract is HME plant extract, the ratio is about 8:2. Preferably, when the plant extract is TVP plant extract, the ratio is about 5:5. Preferably, when the plant extract is HME plant extract, the ratio is about 7:3.
- 10 Preferably, the emulsion gel binder exhibits a G' greater than 20 Pa and a G'' lower than 240 Pa upon heating until 90°C and a G' greater than 100 Pa and a G'' lower than 300 Pa upon subsequent cooling until 60°C, at 1Hz frequency and a strain of 0.2%.

- The lipid may be from any plant source. For example, the lipid may be canola oil, sunflower oil, olive oil, or coconut oil. Preferably, the lipid is canola oil and/or coconut oil, or mixtures thereof.
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Preferably, the emulsion gel binder comprises calcium salt, for example 0.1 to 10 wt.% calcium salt, more preferably 0.5 to 1.5 wt. % calcium salt.

The emulsion gel binder may further comprise vinegar, preferably between 1 to 10 wt.% vinegar.

- 20 The meat analogue may comprise 15 to 75 wt.% plant extract, preferably 25 to 70 wt.% plant extract. Preferably, for a meat analogue comprising TVP plant extract, the meat analogue comprises 20 to 40 wt.%, or about 32 wt.% TVP plant extract. Preferably, for a meat analogue comprising HME plant extract, the meat analogue comprises 45 to 70 wt.%, or about 64 wt.% HME plant extract.
- 25 The plant extract may be derived from legumes, cereals, fruits, or oilseeds. For example, the plant extract may be derived from soy, pea, wheat, faba bean, citrus fruits, or sunflower.

Preferably, the plant extract is soy protein, pea protein, chickpea protein, faba bean protein, sunflower protein, wheat gluten, and combinations of these.

- 30 Preferably, the plant extract is textured protein, for example textured soy protein, textured pea protein, textured chickpea protein, textured faba bean protein, textured lentil protein, textured sunflower protein, and/or combinations of these. More preferably, the plant extract is textured soy protein and/or textured pea protein.

The plant extract may be made by extrusion to make a textured protein.

The optional solid fat may be derived from coconut, shea nut, palm, mango. For example, the optional solid fat may be derived from coconut, for example coconut flakes.

- 5 The meat analogue may be a burger, sausage, minced meat, meatballs or cold cut. Preferably, the meat analogue is a burger. The meat analogue can be cooked, for example deep fried, pan fried, microwaved, oven baked, and combinations of these. The meat analogue can be stored frozen prior or after cooking.

The invention also relates to a meat analogue made according to the method as described herein.

- 10 The invention further relates to the use of a cold set gelling dietary fibre as a binder for a meat analogue.

The invention further relates to the use of a cold set gelling dietary fibre and a heat-set gelling plant based ingredient as a binder for a meat analogue.

- 15 The invention further relates to the use of a cold set gelling dietary fibre and a heat-set gelling plant based ingredient as an emulsion gel binder for a meat analogue.

The invention further relates to the use of water, lipid, heat-set gelling plant based ingredient, cold set gelling dietary fibre, and optionally calcium salt as a binder for a meat analogue.

- 20 In particular, the invention relates to the use of water, lipid, heat-set gelling plant based ingredient, cold set gelling dietary fibre, and optionally calcium salt as a binder for a meat analogue, wherein said water, lipid, heat-set gelling plant based ingredient, cold set gelling dietary fibre, preferably psyllium fibre, and optionally calcium salt are comprised in an emulsion gel binder.

Preferably, the meat analogue is devoid or substantially devoid of additives.

The meat analogue may comprise 20 to 85 wt.%, or 20 to 75 wt.% emulsion gel binder.

- 25 The emulsion gel binder may comprise 0.5 to 20 wt.% cold set gelling dietary fibre, preferably 1 to 10 wt.% cold set gelling dietary fibre, more preferably 1 to 5 wt.% cold set gelling dietary fibre.

The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 20°C may exhibit a shear thinning behavior with zero shear rate viscosity above 100 Pa.s.

The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 7°C may exhibit a G' (storage modulus) greater than 40 Pa and G'' (loss modulus) lower than 150Pa at 1Hz frequency and a strain of 0.2%.

- 5 The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 60°C may exhibit a G' (storage modulus) greater than 4 Pa and G'' (loss modulus) lower than 45Pa at 1Hz frequency and a strain of 0.2%.

The cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 20°C may exhibit a G' (storage modulus) greater than 30 Pa and G'' (loss modulus) lower than 50Pa at 1Hz frequency and a strain of 0.2%.

- 10 Preferably, the cold set gelling dietary fibre has a soluble fraction of greater than 50 %, for example between 50% to 90%, for example about 70%.

- 15 The cold set gelling dietary fibre may be derived from tubers, for example potato, cassava, yam, or sweet potato, or from vegetables, for example carrot, pumpkin, or squash, or from fruit, for example citrus fruit, or from legumes, for example pulses, or from oilseeds, for example flaxseed, or from psyllium, chia seeds, potato, apple, fenugreek, chickpea, carrot, oat, or citrus fruit.

- 20 Preferably, the cold set gelling dietary fibre is derived from psyllium, potato, citrus, or fenugreek. The cold set gelling dietary fibre may comprise psyllium fibre in combination with at least one other fibre, for example citrus fibre, wherein the cold set gelling dietary fibre comprises at least 50% psyllium fibre. The citrus fibre may have a soluble fraction greater than 30%, preferably a soluble fraction greater than 40%. Preferably, the cold set gelling dietary fibre is or comprises psyllium fibre.

Preferably, the emulsion gel binder comprises between 1 to 20 wt.% heat-set gelling plant based ingredient.

- 25 The plant based heat-set gelling ingredient preferably exhibits a G' (storage modulus) greater than 130 Pa and G'' (loss modulus) lower than 60 Pa at 1Hz frequency and a strain of 0.2% at 10 wt. % in an aqueous solution at 60°C, after heating to 90°C.

- 30 Preferably, the heat-set gelling plant based ingredient has a starch content between 30 to 90 wt.%, or between 60 to 80 wt.%, and a protein content between 5 to 40 wt.%, or between 10 to 20 wt.%.

Preferably, the heat-set gelling plant based ingredient has a starch content between 30 to 80 wt.% and a protein content between 10 to 35 wt.%, preferably 15 to 35 wt.%.

The heat-set gelling plant based ingredient may be, for example, quinoa flour, rice flour, buckwheat flour, wheat flour, chickpea flour, pumpkin seed flour, sesame flour, soy flour, chia flour, or combinations of these. Preferably, the heat-set gelling plant based ingredient is quinoa flour or rice flour, most preferably quinoa flour.

- 5 Preferably, the emulsion gel binder comprises (i) heat-set gelling plant based ingredient, and (ii) cold set gelling dietary fibre in a ratio ranging from between 9:1 to 4:6, preferably between 8:2 and 6:4. Preferably, when the plant extract is TVP plant extract, the ratio is about 5:5. Preferably, when the plant extract is HME plant extract, the ratio is about 7:3.

- 10 Preferably, the emulsion gel binder exhibits a G' greater than 20 Pa and a G'' lower than 240 Pa upon heating until 90°C and a G' greater than 100 Pa and a G'' lower than 300 Pa upon subsequent cooling until 60°C, at 1Hz frequency and a strain of 0.2%.

The lipid may be from any plant source. For example, the lipid may be canola oil, sunflower oil, olive oil, or coconut oil. Preferably, the lipid is canola oil and/or coconut oil, or mixtures thereof.

- 15 Preferably, the emulsion gel binder comprises calcium salt, for example 0.1 to 10 wt.% calcium salt, more preferably 0.5 to 1.5 wt. % calcium salt.

The emulsion gel binder may further comprise vinegar, preferably between 1 to 10 wt.% vinegar.

- 20 The optional solid fat may be derived from coconut, shea nut, palm, mango. For example, the optional solid fat may be derived from coconut, for example coconut flakes.

The meat analogue may be a burger, sausage, minced meat, meatballs or cold cut. Preferably, the meat analogue is a burger.

- 25 The meat analogue can be cooked, for example deep fried, pan fried, microwaved, oven baked, and combinations of these. The meat analogue can be stored frozen prior or after cooking.

Detailed description of the invention

Cold set gelling dietary fibre

- 30 Typically, a Newtonian fluid behavior is observed at concentrations below 1 wt.% when the cold set gelling dietary fibre is dispersed in water. Typically, a shear thinning response becomes apparent at concentrations equal or above 1 wt.% when dispersed in water.

A water based solution comprising 6 wt.% of cold set gelling dietary fibre at 7°C may exhibit the following viscoelastic properties (i) shear thinning behavior with zero shear rate viscosity above 100 Pa.s, (ii) G' (storage modulus) greater than 40 Pa and G'' (loss modulus) lower than 150Pa at 1Hz frequency and a strain of 0.2%. Within the scope of this invention, the shear

5 thinning is defined as a rheological property of any material that exhibits a decrease in viscosity with increasing shear rate or applied stress.

Typically, in a cold set gelling dietary fibre of the invention, modulus G' is greater than the modulus G'' up to and including at least 100% of applied strain, at concentrations of 6 wt.% when dispersed in water.

10 **Heat-set gelling plant based ingredient**

Typically, a pre-sheared water based solution comprising 10 wt.% heat-set gelling plant based ingredient at 90°C exhibits the gel-like properties: i. a G' (storage modulus) greater than 130 Pa, and ii. G'' (loss modulus) lower than 60 Pa at 1Hz frequency and a strain 0.2%.

Typically, a pre-sheared water based solution comprising 10 wt.% heat-set gelling plant based

15 ingredient at 60°C exhibits gel-like properties, for example a minimum of 10 fold increase in G' upon heating until 90°C and subsequent decrease to 60°C, or a crossover of G' and G'' upon heating until 90°C and subsequent decrease to 60°C with G' being higher than G'' at 60°C.

The heat-set gelling plant based ingredient may be a combination of ingredients, for example a flour and a plant protein isolate or concentrate, or a starch and a plant protein isolate or

20 concentrate.

Definitions

The compositions disclosed herein may lack any element that is not specifically disclosed herein. Thus, a disclosure of an embodiment using the term "comprising" includes a disclosure of embodiments "consisting essentially of" and "consisting of" and "containing" the

25 components identified. Similarly, the methods disclosed herein may lack any step that is not specifically disclosed herein. Thus, a disclosure of an embodiment using the term "comprising" includes a disclosure of embodiments "consisting essentially of" and "consisting of" and "containing" the steps identified. Any embodiment disclosed herein can be combined with any other embodiment disclosed herein unless explicitly and directly stated otherwise.

Unless defined otherwise, all technical and scientific terms and any acronyms used herein have the same meanings as commonly understood by one of ordinary skill in the art in the field of the invention. Although any compositions, methods, articles of manufacture, or other means or materials similar or equivalent to those described herein can be used in the practice

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of the present invention, the preferred compositions, methods, articles of manufacture, or other means or materials are described herein.

The term “wt.%” used in the entire description below refers to weight % of the total composition, for example the total emulsion gel binder composition, or the total meat analogue composition.

As used herein, “about,” and “approximately” are understood to refer to numbers in a range of numerals, for example the range of -40% to +40% of the referenced number, more preferably the range of -20% to +20% of the referenced number, more preferably the range of -10% to +10% of the referenced number, more preferably -5% to +5% of the referenced number, more preferably -1% to +1% of the referenced number, most preferably -0.1% to +0.1% of the referenced number. All numerical ranges herein should be understood to include all integers, whole or fractions, within the range. Moreover, these numerical ranges should be construed as providing support for a claim directed to any number or subset of numbers in that range. For example, a disclosure of from 1 to 10 should be construed as supporting a range of from 1 to 8, from 3 to 7, from 1 to 9, from 3.6 to 4.6, from 3.5 to 9.9, and so forth.

The term “additive” refers to isolated, extracted polysaccharide molecules which typically undergo chemical modification during manufacturing. The term “additive” includes one or more of modified starches, hydrocolloids (e.g. carboxymethylcellulose, methylcellulose, hydroxypropylmethylcellulose, konjac gum, carrageenans, xanthan gum, gellan gum, locust bean gum, guar gum, alginates, agar, gum arabic, gelatin, Karaya gum, Cassia gum, microcrystalline cellulose, ethylcellulose); emulsifiers (e.g. lecithin, mono and diglycerides, PGPR); whitening agents (e.g. titanium dioxide); plasticizers (e.g. glycerine); anti-caking agents (e.g. silicon-dioxide).

Preferably, the term “additive” includes modified starches, hydrocolloids, and emulsifiers.

Preferably, the term “additive” includes methylcellulose, hydroxypropylmethylcellulose, and konjac gum.

The term ‘emulsion gel’ refers to a semi-solid material comprising a dispersed lipid phase in a continuous water phase. The continuous water phase is structured by soluble, high molecular weight polysaccharides (molecular weight greater than 1 kDa) that can form a cold-set hydrogel via formation of intra-molecular junction zones above a critical concentration, and optionally in the presence of calcium salt. It also refers to biopolymers that can form a hydrogel above a critical concentration via polymer aggregation on heating. The dispersed lipid phase can be liquid oil or crystalized fat.

The term 'cold-set gelling dietary fibre' refers to a dietary fibre that can form a gel on cooling via formation of intra-molecular junction zones, for example hydrogen bonds and ionic crosslinks. In one embodiment, the dietary fibre can form a gel by cooling from 90°C to 60°C.

5 The cold set gelling dietary fibre may be a fibre with a soluble polysaccharide fraction greater than 50 wt.%. The soluble polysaccharide fraction comprises high molecular weight polysaccharides (molecular weight greater than 1 kDa). In one embodiment, the soluble fraction comprises arabinoxylans polysaccharides. In one embodiment, the source of the dietary fibre is from psyllium.

10 The term "fibre" or "dietary fibre" relates to a plant-based ingredient that is not completely digestible by enzymes in the human gut system. Dietary fibres are not isolated, extracted polysaccharide molecules. The manufacturing of dietary fibres are limited to physical processes only, for example grinding, and milling. The term may comprise plant based fibre-rich fraction obtained from tubers, for example potato, cassava, yam, or sweet potato, or from vegetables, for example carrot, pumpkin, or squash, or from fruit, for example citrus fruit, or
15 from legumes, for example pulses, or from oilseeds, for example flaxseed, or from potato, apple, psyllium, fenugreek, chickpea, carrot, chia or citrus fruit. The dietary fibre may comprise arabinoxylans, cellulose, hemicellulose, pectin, and/or lignin.

The term "calcium salt" refers to salts of calcium such as calcium chloride, calcium carbonate, calcium citrate, calcium gluconate, calcium lactate, calcium phosphate, calcium
20 glycerophosphate and the like, and mixtures thereof. Preferably, the calcium salt is calcium chloride. All examples shown herein use calcium chloride. The amount of calcium salt typically ranges from 0.5 to 5 wt.%.

The terms "food", "food product" and "food composition" mean a product or composition that is intended for ingestion by an animal, including a human, and provides at least one
25 nutrient to the animal or human. The present disclosure is not limited to a specific animal.

The term "high shear" as used herein means the use of shear at least 1000 rpm, or at least 2000 rpm.

A "meat-analogue" is also called a meat alternative, meat substitute, mock meat, faux meat, imitation meat, or (where applicable) vegetarian meat or vegan meat. Meat analogue is
30 understood to mean a food made from non-meats, without other animal products, such as dairy. Therefore protein from animal source is completely absent. Protein from animal source is animal meat protein and/or milk protein. A meat-analogue food product is a composition in which meat (i.e. skeletal tissue and non- skeletal muscle from mammals, fish and fowl) and meat by-products (i.e. the non-rendered clean parts, other than meat, derived from
35 slaughtered mammals, fowl or fish) are completely absent. The market for meat imitations includes vegetarians, vegans, non-vegetarians seeking to reduce their meat consumption for health or ethical reasons, and people following religious dietary laws.

The term “binder” or “binding system” as used herein relates to a substance for holding together particles and/or fibres in a cohesive mass. It is an edible substance that in the final product is used to trap components of the foodstuff with a matrix for the purpose of forming a cohesive product and/or for thickening the product. Binding systems of the invention may contribute to a smoother product texture, add body to a product, help retain moisture and/or assist in maintaining cohesive product shape; for example, by aiding particles to agglomerate.

The term “substantially devoid” insofar as it relates to an ingredient means that the ingredient is present in an amount of less than 0.1 wt.%, or is entirely absent.

The term “textured protein” as used herein refers to plant extract material, preferably derived from legumes, cereals or oilseeds. For example, the legume may be soy or pea, the cereal may be gluten from wheat, the oilseed may be sunflower. In one embodiment, the textured protein is made by extrusion. This can cause a change in the structure of the protein which results in a fibrous, spongy matrix, similar in texture to meat. The textured protein can be dehydrated or non-dehydrated. In its dehydrated form, textured protein can have a shelf life of longer than a year, but will spoil within several days after being hydrated. In its flaked form, it can be used similarly to ground meat.

The term “cereals” includes wheat, rice, maize, barley, sorghum, millet, oats, rye, triticale, fonio and pseudocereals (e.g. amaranth, breadnut, buckwheat, chia, cockscomb, pitseed, goosefoot, quinoa, and wattleseed).

Brief description of figures

Figure 1: G' , G'' and $\tan \delta$ as function of frequency for a range of psyllium fibre gels with an increased concentration. The error bars represent the standard deviation of two measurements.

Figure 2: G' , G'' and $\tan \delta$ as function of frequency for a range of psyllium fibre gels with an increased concentration. The error bars represent the standard deviation of two measurements.

Figure 3: G' , G'' and $\tan \delta$ as function of frequency for a range of psyllium fibre gels with an increased concentration. The error bars represent the standard deviation of two measurements.

Figure 4: Apparent viscosity values of apple, citrus, potato and psyllium aqueous fibre systems at a shear rate of 0.01 s^{-1} and temperature of 7°C .

Figure 5 : Frequency dependence of the 6 wt.% psyllium fibre, 6 wt. % potato fibre and 6 wt. % (psyllium fibre + citrus fibre). The error bars represent the standard deviation of two measurements.

Figure 6: G' , G'' (Pa) and $\tan \delta$ as function of frequency for psyllium fibre solutions (10 wt.%) measured at constant strain of 0,2%, within the linear viscoelastic region, and temperature and temperature of 60°C after heating from 7°C to 90°C at a heating rate of 5°C/min, and cooling to 60°C at 5°C/min. The error bars represent the standard deviation of two measurements.

Figure 7: $\tan \delta$ as function of temperature for psyllium fibre solutions (10 wt.%) measured at constant strain of 0,2% and temperature and temperature of 60°C after heating from 7°C to 90°C at a heating rate of 5°C/min, and cooling to 60°C at 5°C/min. The error bars represent the standard deviation of two measurements.

Figure 8: $\tan \delta$ as function of frequency for 25 wt.% pre-sheared quinoa flour aqueous dispersions, measured at constant strain of 0,2% and temperature of 7°C and at 60°C after heating from 7°C to 90°C at a heating rate of 5°C/min. The error bars represent the standard deviation of two measurements.

Figure 9: 10 wt.% quinoa solution before (A,C) and after heating until 90°C and subsequent cooling to 60°C (B,D) and with (C,D) and without (A,B) treatment using a Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen).

Figure 10: G' , G'' (Pa) as function of temperature for quinoa flour aqueous dispersions after pre-shearing process in Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen) and High-Pressure homogenizer (two times at 500 Pa). The error bars represent the standard deviation of two measurements.

Figure 11: G' (Pa) absolute values of an emulsion gel before heating (7°C) and temperature of 60°C after heating from 7°C to 90°C at a heating rate of 5°C/min, measured at constant frequency of 1Hz and strain of 0.2%. (6.4 wt.% quinoa flour, 1.6 wt.% psyllium fibre, 2.1 wt.% vinegar, 0.4 wt.% calcium chloride, 20 wt.% canola oil). The error bars represent the standard deviation of two measurements.

Figure 12: G' (Pa), and G'' (Pa) of the emulsion gel binder (6.4 wt.% quinoa flour, 1.6 wt.% psyllium fibre, 2.1 wt.% vinegar, 0.4 wt.% calcium chloride, 20 wt.% canola oil) as function of temperature. The error bars represent the standard deviation of two measurements.

Figure 13: Confocal laser scanning microscopy (CLSM) images of emulsion gels (6.4 wt.% quinoa flour, 1,6 wt. % psyllium fibre, 20 wt.% canola oil) comprising psyllium fibre and quinoa flour in aqueous phase, and canola oil as dispersed phase.

Figure 14: Scanning Electron Microscopy (SEM) images of emulsion gel (6.4 wt.% quinoa flour, 1,6 wt. % psyllium fibre, 20 wt. % canola oil) comprising psyllium fibre and quinoa flour in aqueous phase, and canola oil as dispersed phase. The samples were imaged at before heating at 7 °C (image A), and after heating to 90°C and cooling to 7°C (image B).

Figure 15 - $\tan \delta$ as function of frequency for the emulsion gels (2.7 wt.% quinoa flour, 2.2 wt.% psyllium fibre, 0.8 wt.% calcium chloride, 3.7 wt.% vinegar, 17.8 wt.% canola oil) produced using a Silverson L5M-A mixer and a Ultra-Turrax T25 basic, measured at

temperature of 60°C after cooling from 90°C at a cooling rate of 5°C/min. The error bars represent the standard deviation of two measurements.

EXAMPLES

5 Example 1

Dietary fibre compositions

Table 1 below shows examples of dietary fibres which can be used as single systems or in combination as part of the emulsion gel system. Apple fibre is shown as a negative example. The selection of fibre is based on both composition and rheological properties in aqueous solution.

Table 1

	Psyllium fibre	Potato fibre	Citrus fibre	Apple fibre
Total dietary fibre	89 %	92 %	74%	55%
Soluble fibre	70 %	73%	36%	10%
Insoluble fibre	17 %	19%	38%	45%
Starch	0%	0%	0%	0%
Free sugars	0%	<2%	8%	N.A.

Fibres were analyzed according to the official methods of analysis of AOAC International (2005) 18th ed., AOAC International, Gaithersburg, MD, USA, Official Method 991.43. (modified).

Example 2

Mechanical spectra of psyllium fibre gels at 7°C

Psyllium fibre solutions were prepared by dispersing the psyllium fibre water in a lab scale mixer for 5 min, and left overnight to ensure complete hydration.

The rheological properties of the fibre suspensions and gels were assessed using a stress-controlled rheometer (Anton Paar MCR 702) equipped with a 50 mm-diameter, serrated plate/plate set-up. To prevent evaporation the sample was covered with a layer of mineral oil and a hood equipped with an evaporation blocker was used.

Figure 1 shows the mechanical spectra (frequency sweeps) of psyllium fibre gels at a range of concentrations in cold conditions. The gel-like response can be seen for all the concentrations where G' is greater than G'' and nearly independent of frequency, and a $\tan \delta$ value of 0.2. This rheological fingerprint in cold conditions is required for structuring the water phase of the emulsion gel which will then be used as binder in the meat analogue.

The figure shows G' , G'' and $\tan \delta$ as function of frequency for a range of psyllium fibre gels with an increased concentration. Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz (within the linear viscoelastic region). After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%.

Error bars represent the standard deviation of two measurements.

10 Example 3

Mechanical spectra of psyllium fibre gels at 60°C

Psyllium fibre solutions were prepared by dispersing the psyllium fibre water in a lab scale mixer for 5 min, and left overnight to ensure complete hydration.

Figure 2 shows the mechanical spectra (frequency sweeps) of psyllium fibre gels at a range of concentrations in hot conditions.

The figure shows G' , G'' and $\tan \delta$ as function of frequency for a range of psyllium fibre gels with an increased concentration. Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 90°C at a heating rate of 5°C/min, followed by a 1 minute holding at 90°C and a subsequent cooling step from 90°C to 60°C at 5°C/min. A holding step at 60°C was then applied for 15 minutes (constant strain of 0,2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 60°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

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Example 4

Mechanical spectra of potato fibre gels at 7°C

Figure 3 shows the mechanical spectra (frequency sweeps) of potato fibre gels at a range of concentrations in cold conditions.

The figure shows G' , G'' and $\tan \delta$ as function of frequency for a range of psyllium fibre gels with an increased concentration. Oscillatory rheological measurements were carried out to

monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 85°C at a heating rate of 5°C/min, followed by a 5 minute holding at 85°C and a subsequent cooling step from 85°C to 7°C at 5°C/min. A holding step at 7°C was then applied for 15 minutes (constant strain of 0,2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 7°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

Example 5

15 Apparent viscosity values of fibre dispersions

Figure 4 shows the apparent viscosity values of the psyllium, potato and apple fibres. The low viscosity value of the predominantly insoluble, apple fibre fraction makes it unsuitable to be used to form an emulsion gel and hence an effective binder for meat analogue. The apple fibre forms a particulate dispersion where the particles sediment whereas both psyllium and potato fibre have the ability to structure the water phase due to the increased hydrodynamic volume of their soluble, high molecular weight polysaccharides (molecular weight greater than 1 kDa). In cold conditions, intramolecular hydrogen bonding occurs, hence imparting a gel-like behavior (e.g. presence of an elastic moduli G'), of those fibre-based dispersions.

The figure shows apparent viscosity values of apple, citrus, potato and psyllium aqueous fibre systems at a shear rate of 0.01 s^{-1} and temperature of 7°C. A pre-shearing step at $10 \text{ s}^{-1} / 1 \text{ min}$ was first applied to the samples at a constant temperature of 7°C, following by a resting step of 10 min at 7°C. Shear rate was then increased from $1 \cdot 10^{-5} \text{ s}^{-1}$ to 1000 s^{-1} in 6 min, then from 1000 s^{-1} to $1 \cdot 10^{-5} \text{ s}^{-1}$ in 6 min.

These fibre-based aqueous dispersions were prepared by dispersing the fibres water in a lab scale mixer for 5 min, and left overnight to ensure complete hydration.

Example 6

Apparent viscosity values of fibre dispersions

Fibre-based aqueous dispersions were prepared by dispersing the fibres in water in a lab scale mixer for 5 min, and left overnight to ensure complete hydration prior to carrying out the rheological measurements.

Figure 5 shows frequency dependence of $\tan\delta$ for psyllium fibre gels, potato fibre gels, and psyllium + citrus fibre mixed gels. A low $\tan\delta$ and independent of frequency indicates a strong, continuous gel-like network. Hence, potato, psyllium and a citrus/psyllium (6:4) mixed fibre system is the preferred choice for creating an emulsion gel to be used as a binder in the meat analogue.

In figure 5, frequency dependence of the 6 wt.% psyllium fibre, 6 wt. % potato fibre and 6 wt. % (a citrus/psyllium (6:4) mixed fibre system). Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 85°C at a heating rate of 5°C/min, followed by a 5 minute holding at 85°C and a subsequent cooling step from 85°C to 7°C at 5°C/min. A holding step at 7°C was then applied for 15 minutes (constant strain of 0.2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 7°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

Example 7

Effect of calcium on psyllium fibre gel strength

Figure 6 shows strengthening of the psyllium fibre gel network in the presence of calcium chloride, as the value of G' is increased and G'' shows a lower frequency dependence compared to the same psyllium fibre gels without added calcium chloride. Increasing the gels also improves binder properties in the burger.

Psyllium fibre solutions were prepared by dispersing the psyllium fibre and calcium chloride in water in a lab scale mixer for 1 min, and left overnight to ensure complete hydration, prior to carrying out the rheological measurements.

Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 90°C at a heating rate of 5°C/min, followed by a 1 minute holding at 90°C and a subsequent cooling step from 90°C to 60°C at 5°C/min. A holding step at 60°C was then applied for 15 minutes (constant strain of 0.2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 60°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4

minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

Figure 7 shows the strengthening of the psyllium fibre gel network in presence of calcium salt upon heating. Upon heating, the maximum $\tan \delta$ of the psyllium fibre gel without calcium remains higher than the psyllium fibre gel with added psyllium fibre, thus improving the stability upon heating. In a burger, this will result in a better stability upon cooking.

Psyllium fibre solutions were prepared by dispersing the psyllium fibre and calcium salt in water in a lab scale mixer for 1 min, and left overnight to ensure complete hydration, prior to carrying out the rheological measurements.

In figure 7, $\tan \delta$ as function of temperature for psyllium fibre solutions (10 wt.%) measured at constant strain of 0,2% and temperature and temperature of 60°C after heating from 7°C to 90°C at a heating rate of 5°C/min, and cooling to 60°C at 5°C/min. Psyllium fibre solutions were prepared by dispersing the psyllium fibre powder to water in a lab scale mixer for 1 min, and left overnight to ensure complete hydration.

Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 90°C at a heating rate of 5°C/min, followed by a 1 minute holding at 90°C and a subsequent cooling step from 90°C to 60°C at 5°C/min. A holding step at 60°C was then applied for 15 minutes (constant strain of 0,2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 60°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

Example 8

Heat-set gelling properties of pre-sheared quinoa flour water-dispersions

Figure 8 shows $\tan \delta$ the change in frequency dependence of quinoa flour dispersions before and after heating until 90°C and cooling to 60 °C. After heating there is a lower frequency dependence, indicating the formation of a gel. This is important for the “cook from raw” effect in the burger, during which the burger becomes firmer upon heating.

Quinoa flour aqueous dispersions (25 wt.%) were prepared with a lab scale mixer (1 min) and left overnight to ensure full hydration. Afterwards high shear is applied using a Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen).

5 In figure 8, $\tan \delta$ as function of frequency for 25 wt.% pre-sheared quinoa flour aqueous dispersions, measured at constant strain of 0.2% and temperature of 7°C and at 60°C after heating from 7°C to 90°C at a heating rate of 5°C/min.

Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 90°C at a heating rate of 5°C/min, followed by a 1 minute holding at 90°C and a subsequent cooling step from 90°C to 60°C at 5°C/min. A holding step at 60°C was then applied for 15 minutes (constant strain of 0.2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 60°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

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Example 9

Heat-set gelling properties of pre-sheared and non pre-sheared quinoa flour water-dispersions

25 Figure 9 pictures show that a high shear treatment is needed to form a continuous gel network from quinoa flour after heating. This is needed in the burger where a strong, continuous gel is required in hot conditions to prevent crumbling and provide a hot bite during consumption.

Figure 9-B shows a dispersion of quinoa flour particles where water phase 'leaks out' of the system, after heating. Figure 9-D shows a continuous gelled-like material resulting from applying the same heat treatment to pre-sheared quinoa flour water dispersion.

30 Quinoa flour aqueous dispersions (10 wt.%) were prepared with a lab scale mixer (1 min) and left overnight to ensure full hydration. Afterwards high shear was applied using a Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen) for the samples 9 C-D.

Figure 9 shows a 10 wt.% quinoa flour solution before (A,C) and after heating until 90°C and subsequent cooling to 60°C (B,D) and with (C,D) and without (A,B) treatment using a Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen).

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Example 10

Effect of different pre-shearing conditions on heat-set gelling properties of quinoa flour water-dispersions

Figure 10 shows the gelation of quinoa flour upon heating as G' increases on heating to 90°C (cooking temperature) and remains with values of similar magnitude (within error bars) when cooling to 60°C (consumption temperature). High pressure-homogenization has a positive effect on gelling properties as particle size is reduced hence increasing surface area thereby increasing solubilization of the gelling biopolymers present (protein, starch).

Quinoa flour aqueous dispersions (10 wt.%) were prepared with a lab scale mixer (1 min) and left overnight to ensure full hydration. In case of the Silverson L5M-A a high shear is applied using a Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen). High pressure homogenization was applied with a High-Pressure homogenizer (Niro Soavi Panda) with two runs at 500 Pa.

In figure 10, G' , G'' (Pa) as function of temperature for quinoa flour aqueous dispersions after pre-shearing process in Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen) and High-Pressure homogenizer (two times at 500 Pa). Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 90°C at a heating rate of 5°C/min, followed by a 1 minute holding at 90°C and a subsequent cooling step from 90°C to 60°C at 5°C/min. A holding step at 60°C was then applied for 15 minutes (constant strain of 0.2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 60°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

Example 11

Gel strength of emulsion gel binder in cold and in hot (eating temperature)

Figure 11 shows that the gel strength of binder, indicated by the value of G' , increases after heating to 90°C and subsequent cooling to 60°C.

Samples were prepared by dispersing the quinoa flour, psyllium fibre, calcium chloride and vinegar in water in a lab scale mixer for 1 minute, and left overnight to ensure complete hydration. The next day the canola oil was added and a high shear was applied using Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen).

Figure 11 shows G' (Pa) absolute values of an emulsion gel before heating (7°C) and temperature of 60°C after heating from 7°C to 90°C at a heating rate of 5°C/min, measured at

constant frequency of 1Hz and strain of 0.2%. (6.4 wt.% quinoa flour, 1.6 wt.% psyllium fibre, 2.1 wt.% vinegar, 0.4 wt.% calcium chloride, 20 wt.% canola oil).

Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 90°C at a heating rate of 5°C/min, followed by a 1 minute holding at 90°C and a subsequent cooling step from 90°C to 60°C at 5°C/min. A holding step at 60°C was then applied for 15 minutes (constant strain of 0.2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 60°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Example 12

Temperature dependence of emulsion gel binder' G' , following a cooking and eating temperature conditions

Figure 12 shows the G' (Pa), and G'' (Pa) of the emulsion gel binder (6.4 wt.% quinoa flour, 1.6 wt.% psyllium fibre, 2.1 wt.% vinegar, 0.4 wt.% calcium chloride, 20 wt.% canola oil) as a function of temperature. A sequential two step gelling process is shown: On heating to cooking temperature (90°C), a concurrent quinoa starch gelatinization followed by quinoa protein gelation takes place, leading to an increase in G' (elastic moduli) from 143 Pa to 172 Pa. On cooling from 90°C to consumption temperature (60°C), psyllium fibre starts to gel hence leading to a further increase in G' from 172 Pa to 408 Pa. This is the optimal gel-like properties when used as a binder in a meat analogue application, allowing the 'meat' pieces to hold together during cooking as well as imparting a firm bite during consumption.

In figure 12, G' (Pa), and G'' (Pa) of the emulsion gel binder (6.4 wt.% quinoa flour, 1.6 wt.% psyllium fibre, 2.1 wt.% vinegar, 0.4 wt.% calcium chloride, 20 wt.% canola oil) as function of temperature.

Oscillatory rheological measurements were carried out to monitor the sol-to-gel transition of the different fibers as function of temperature. A resting step of 5 minutes was initially applied to equilibrate the material at 7°C, constant strain of 0.2% and frequency of 1 Hz. After this a frequency sweep was applied, during which the frequency was increased from 0.01 to 10 Hz within 4 minutes at a constant strain of 0.2%. The loss and storage modulus was then measured at a frequency of 1Hz and a strain of 0.2% while heating from 7°C to 90°C at a heating rate of 5°C/min, followed by a 1 minute holding at 90°C and a subsequent cooling step from 90°C to 60°C at 5°C/min. A holding step at 60°C was then applied for 15 minutes (constant strain of 0.2% and frequency of 1 Hz) followed by frequency and amplitude sweep tests at 60°C. During frequency sweeps, the frequency was increased from 0.01 to 10 Hz within 4

minutes at a constant strain of 0.2%. During strain sweeps, the strain was increased from 0.1 to 100% within 4 minutes at a constant frequency of 1 Hz.

Error bars represent the standard deviation of two measurements.

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Example 13

Change in the emulsion gel microstructure after heating

Microscopy pictures indicating a change in the microstructure provided by the protein gelation after heating (Figure 13). After heating, gelled proteins (in green) appeared at the surface of the oil droplets (in red) as well as the continuous water phase, thus contributing to the gel-like material properties of the emulsion gel binding system. This denser crosslinked gel network of the continuous phase in hot conditions prevents the burger to crumble during cooking and provides a firm, "meaty" bite during consumption.

Emulsion gel samples were prepared by dispersing the quinoa flour, psyllium fibre and calcium chloride in water using a lab scale mixer for 1 minute, and left overnight to ensure complete hydration. The next day the canola oil was added and a high shear was applied using Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen).

Figure 13 shows confocal laser scanning microscopy (CLSM) images of emulsion gels (6.4 wt.% quinoa flour, 1,6 wt. % psyllium fibre, 20 wt.% canola oil) comprising psyllium fibre and quinoa flour in aqueous phase, and canola oil as dispersed phase. The samples were imaged at before heating at 7 °C (image A), and after heating to 90°C and cooling to 7°C (image B), using a LSM 710 confocal microscope equipped with an Airyscan detector (Zeiss, Oberkochen, Germany). The samples were loaded inside a 1 mm plastic chamber closed by a glass coverslip to prevent compression and drying artefacts. The image acquisition was performed using an excitation wavelength of 488 and 561 nm, for the Na-Fluorescein and Nile red, respectively.

Example 14

Change in the emulsion gel microstructure after heating

Microscopy pictures indicate a change in microstructure after heating (Figure 14). Before heating there are starch granules present (~1-3 µm, with flatted sides), which have gelatinized after heating. The crosslinking density of the emulsion gel continuous phase increases after heating.

Emulsion gel samples were prepared by dispersing the quinoa flour, psyllium fibre and calcium chloride in water using a lab scale mixer for 1 minute, and left overnight to ensure complete hydration. The next day the canola oil was added and a high shear was applied using Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen).

Figure 14 shows scanning Electron Microscopy (SEM) images of emulsion gel (6.4 wt.% quinoa flour, 1,6 wt. % psyllium fibre, 20 wt.% canola oil) comprising psyllium fibre and quinoa flour in aqueous phase, and canola oil as dispersed phase. The samples were imaged at before heating at 7 °C (image A), and after heating to 90°C and cooling to 7°C (image B).

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Example 15

Gel-like properties of emulsion gel binders produced using Silverson and Ultra-Turrax equipment

Figure 15 shows a low frequency dependence of $\tan \delta$ for the emulsion gels prepared with the Ultra-Turrax and Silverson L5M-A mixer and a $\tan \delta$ values between 0,15 and 0,2 at temperature of 60°C, indicating that both mixers can be used to prepare an emulsion gel system with the optimal rheological properties to be used at binder in a meat analogue.

Silverson L5M-A mixer: Samples were prepared by dispersing the quinoa flour, psyllium fibre and calcium chloride in water in a lab scale mixer for 1 minute, and left over night for hydration, afterwards the canola oil was added and a high shear was applied using Silverson L5M-A mixer (2 min at 8000 rpm; 2mm emulsor screen).

Ultra-Turrax T25 basic mixer: Samples were prepared by dispersing the quinoa flour, psyllium fibre and calcium chloride in water in a lab scale mixer for 1 minute, and left over night for hydration, afterwards the canola oil was added and a high shear was applied using an Ultra-Turrax T25 basic (2 min at speed 5).

Figure 15 shows $\tan \delta$ as function of frequency for the emulsion gels (2.7 wt.% quinoa flour, 2.2 wt.% psyllium fibre, 0.8 wt.% calcium chloride, 3.7 wt.% vinegar, 17.8 wt.%) produced using a Silverson L5M-A mixer and a Ultra-Turrax T25 basic, measured at temperature of 60°C after cooling from 90°C at a cooling rate of 5°C/min. Error bars represent the standard deviation of two measurements.

Example 16**Plant based burger recipes**

Plant based burgers were prepared according to the recipes shown below in Tables 2 and 3:

5 **Table 2**

	Recipe 1 – Soy TVP no gluten	Recipe 2 – Soy TVP with gluten	Recipe 3 – Pea TVP Pea with gluten	Recipe 4 – Soy HME	Recipe 5 – Soy TVP with gluten – coconut in binder
<i>Texturized protein – Soy TVP</i>	29.88%	28.44%			29.19%
<i>Texturized protein – Pea TVP</i>			33.77%		
<i>Texturized protein Soy HME</i>				63.39%	
<i>Coconut flakes</i>	3.70%	3.52%	3.34%	3.92%	1.05%
<i>Flavor</i>					
<i>Salt</i>	0.89%	0.85%	0.80%		0.85%
<i>TVP Flavor Mix</i>	2.73%	2.60%	2.48%		2.60%
<i>Malt extract</i>	0.92%	0.88%	0.84%	0.23%	0.88%
<i>Savory Base</i>	0.37%	0.35%	0.34%	0.00%	0.35%
<i>HME Flavour mix</i>				2.02%	
<i>Binder</i>					
<i>Quinoa flour</i>	1.68%	1.59%	1.82%	3.15%	1.57%
<i>Psyllium fibre</i>	1.38%	1.31%	1.50%	2.05%*	1.29%
<i>Calcium chloride</i>	0.47%	0.44%	0.51%	0.26%	0.44%
<i>vinegar</i>	2.10%	2.15%	2.10%	2.90%	2.13%
<i>water</i>	44.81%	42.62%	34.39%	16.81%	42.03%
<i>Canola oil</i>	11.05%	10.44%	8.51%	5.25%	10.34%
<i>coconut flakes melted</i>					2.49%
<i>Gluten</i>					
<i>gluten</i>		1.80%	3.60%		1.80%

<i>ascorbic acid</i>		0.02%	0.04%		0.02%
<i>Vinegar</i>		0.24%	0.49%		0.24%
<i>Water for gluten</i>		2.73%	5.48%		2.73%
<i>total</i>		100.00%	100.00%	100.00%	100.00%
				*Of which 1% added together with the flavor	

Each of the burgers made by the recipes in the table 2 had the following characteristics during preparation (e.g. molding in cold), handling (including cooking) and consumption.

- 5 - preparation: mixture can be molded into burgers, and stay in the same shape after removal from the mold;
- handling: molded burgers are firm and hold their structure, do not crumble during cooking process such as flipping in the pan;
- consumption:
- 10 o burgers can easily be cut and picked up with a fork without falling apart while still hot
- o burgers impart a firm bite in mouth and do not lose crumble upon consumption
- o burgers do not impart a mushy or slimy mouthfeel.
- 15 The burger recipes shown in table 3 below were prepared for comparison purposes:

Table 3

	Recipe 6 – Soy TVP gluten – with sesame	Recipe 7 – Soy TVP with gluten – with rice flour	Recipe 8 – Soy TVP with gluten – with chickpea	Recipe 9 – Soy TVP with gluten – with soy protein concentrate
<i>Texturized protein – Soy TVP</i>	28.44%	28.44%	28.44%	28.44%
<i>Texturized protein – Pea TVP</i>				
<i>Coconut flakes</i>	3.52%	3.52%	3.52%	3.52%
Flavor				

<i>Salt</i>	0.85%	0.85%	0.85%	0.85%
<i>TVP Flavor Mix</i>	2.60%	2.60%	2.60%	2.60%
<i>Malt extract</i>	0.88%	0.88%	0.88%	0.88%
<i>Savory Base</i>	0.35%	0.35%	0.35%	0.35%
Binder				
<i>Quinoa flour</i>	0.80%			0.53%
<i>rice flour</i>		1.59%		
<i>Chickpea flour</i>			1.59%	
<i>soy protein concentrate</i>				1.06%
<i>Psyllium fibre</i>	1.31%	1.31%	1.31%	1.31%
<i>Calcium chloride</i>	0.44%	0.44%	0.44%	0.44%
<i>Vinegar</i>	2.15%	2.15%	2.15%	2.15%
<i>Water</i>	42.62%	42.62%	42.62%	42.62%
<i>Sesame seeds grinded</i>	0.80%			
<i>Canola oil</i>	10.44%	10.44%	10.44%	10.44%
Gluten				
<i>Gluten</i>	1.80%	1.80%	1.80%	1.80%
<i>ascorbic acid</i>	0.02%	0.02%	0.02%	0.02%
<i>Vinegar</i>	0.24%	0.24%	0.24%	0.24%
<i>Water for gluten</i>	2.73%	2.73%	2.73%	2.73%
total	100.00%	100.00%	100.00%	100.00%

Each of the burgers made by the recipes in the tables 3 had the following characteristics during preparation (e.g. molding in cold), handling (including cooking) and consumption.

- 5 - preparation: mixture can be molded into burgers, and stay in the same shape after removal from the mold;
- handling: molded burgers are firm and hold their structure, do not crumble during heating and flipping in the pan;

The burgers differed in characteristics upon consumption:

Recipe 6 Soy TVP gluten– with sesame: bite not as firm as recipe 2.

- 10 Recipe 7 Soy TVP gluten– with rice flour: bite not as firm as in recipe 2.

Recipe 8 Soy TVP gluten– with chickpea: bite not as firm as in recipe 2, slight off flavour.

Recipe 9 Soy TVP gluten– with soy protein concentrate: bite not as firm as in recipe 2, more mushy than recipe 2.

- 15 **Table 4**

	Recipe 10 – Soy TVP with more oil	Recipe 11 – Soy TVP with less quinoa flour and psyllium fibre	Recipe 12 – Soy TVP with gluten with apple fibre
<i>Texturized protein – Soy TVP</i>	31.79%	29.5%	28.44%
<i>Coconut flakes</i>	3.94%	5.25%	3.52%
Flavor			
<i>Salt</i>	0.95%	0.82%	0.85%
<i>TVP Flavor Mix</i>	2.91%	2.53%	2.60%
<i>Malt extract</i>	0.98%	0.86%	0.88%
<i>Savory Base</i>	0.39%	0.34%	0.35%
Binder			
<i>Quinoa flour</i>	1.54%	1.68%	
<i>soy protein isolate</i>			1.59%
<i>Psyllium fibre</i>	1.27%	0.3 %	
<i>Apple fibre</i>			1.31%
<i>Calcium chloride</i>	0.43%	0.30%	0.44%
<i>vinegar</i>	2.10%	2.11%	2.15%
<i>water</i>	36.06%	44.12%	42.62%
<i>Canola oil</i>	17.63%	12.13%	10.44%
Gluten			
<i>gluten</i>			1.80%
<i>ascorbic acid</i>			0.02%
<i>Vinegar</i>			0.24%
<i>Water for gluten</i>			2.73%
total	100.00%	100.00%	100.00%

The burgers made by the recipes in table 5 had the following characteristics during preparation, handling, and consumption.

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Recipe 10: Soy TVP with more canola oil

- Oily burger with fatty mouthfeel
- No firm bite
- Less firm than the reference (soy TVP gluten).

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Recipe 11: Soy TVP with less quinoa flour and psyllium fibre

- Burger easily falls apart before cooking
- Burger could not be cut and picked up with a fork
- Burger was very crumbly and did not impart a firm bite.

15

Recipe 12: Soy TVP gluten with apple fibre

- Burger held together when molded
 - Burger easily fell apart before cooking
 - Burger could not be cut and picked up with a fork in hot conditions
- 5 - Burger was very crumbly and did not impart a firm bite.

10

Claims

1. A method of making a meat analogue, said method comprising
 - a. Mixing in water a cold set gelling dietary fibre, preferably psyllium fibre; a heat-set gelling plant based ingredient, preferably flour; and optionally calcium salt to form a binder aqueous phase;
 - b. Adding lipid to the binder aqueous phase and homogenizing to form an emulsion gel binder;
 - c. Mixing plant extract with the emulsion gel binder, optionally adding solid fat, and optionally molding, to form a meat analogue.
2. The method according to claim 1, wherein the meat analogue comprises 20 to 85 wt.% emulsion gel binder.
3. The method according to claims 1 or 2, wherein the emulsion gel binder comprises 0.5 to 20 wt.% cold set gelling dietary fibre.
4. The method according to claims 1 to 3, wherein the cold set gelling dietary fibre at 6 wt. % in an aqueous solution at 7°C exhibits a G' (storage modulus) greater than 40 Pa and G'' (loss modulus) lower than 150Pa at 1Hz frequency and a strain of 0.2%.
5. The method according to claims 1 to 4, wherein the cold set gelling dietary fibre has a soluble fraction of greater than 50 wt.%.
6. The method according to claims 1 to 5, wherein the cold set gelling dietary fibre is or comprises psyllium fibre.
7. The method according to claims 1 to 6, wherein the heat-set gelling plant based ingredient exhibits a G' (storage modulus) greater than 130 Pa and G'' (loss modulus) lower than 60 Pa at 1Hz frequency and a strain of 0.2% at 10 wt. % in an aqueous solution at 60°C, after heating to 90°C.
8. The method according to claims 1 to 7, wherein the heat-set gelling plant based ingredient comprises between 60 to 80 wt.% starch and between 10 to 20 wt.% protein.
9. The method according to claims 1 to 8, wherein the heat-set gelling plant based ingredient is quinoa flour.
10. The meat analogue according to claims 1 to 9, wherein the emulsion gel binder exhibits a G' greater than 20 Pa and a G'' lower than 240 Pa upon heating until 90°C and a G'

greater than 100 Pa and a G" lower than 300 Pa upon subsequent cooling until 60°C, at 1Hz frequency and a strain of 0.2%.

5 11. The method according to claims 1 to 10, wherein the emulsion gel binder comprises 0.1 to 10 wt.% calcium salt.

10 12. The method according to claims 1 to 11, wherein the plant extract is textured vegetable protein, for example textured soy protein, textured pea protein, textured chickpea protein, textured faba bean protein, textured lentil protein, textured sunflower protein, and/or combinations of these.

13. The method according to claims 1 to 12, wherein the meat analogue is a burger.

15 14. A meat analogue comprising

- a. Plant extract;
- b. Optional solid fat; and
- c. Emulsion gel binder comprising
 - 20 i. Cold set gelling dietary fibre, preferably psyllium fibre;
 - ii. Heat-set gelling plant based ingredient, preferably flour;
 - iii. Lipid;
 - iv. Water; and
 - v. Optional calcium salt.

25 15. Use of water, lipid, heat-set gelling plant based ingredient, cold set gelling dietary fibre, and optionally calcium salt as a binder for a meat analogue, wherein said water, lipid, heat-set gelling plant based ingredient, cold set gelling dietary fibre, preferably psyllium fibre, and optionally calcium salt are comprised in an emulsion gel binder.

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