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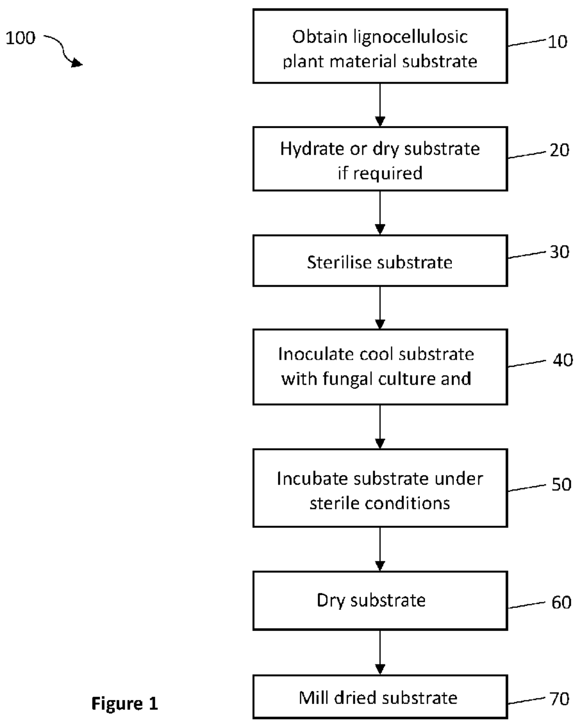

Figure 1

(57) Abstract: The invention describes a food or flour composition derived from fungal fermentation of plant material, the flour composition having a total metabolizable carbohydrate level of between 0.1 - 50% by weight. Also described are processes for the manufacture of the food or flour compositions using fungal fermentation having a total metabolizable carbohydrate level of between 0.1 - 50% by weight.

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A Process and Composition for an Improved Flour Product

Field of Invention

This invention relates to an improved food product and a process for making the improved food product. More specifically, the improved food product is a low-calorie flour product produced by the fermentation of plant material by higher fungi.

Background to the Invention

The majority of flour used in the food industry and in traditional cooking and baking methods is derived from a range of different plant materials, particularly cereals, which have been ground into a fine powder.

Flour is traditionally made by grinding the plant material, such as wheat. Different parts of the wheat grain are used to make different types of flour. Some fruit and vegetable flours are known but these are formed by simply drying the fruit or vegetable and then grinding or milling the dried fruit or vegetable into flour. For example apple, blueberry, grape or plum fibre made by Marshall Ingredients (www.marshallingredients.com). Due to the high content of simple sugars and/or starch of many fruits and vegetables, such flours consequently remain high in metabolizable carbohydrates.

The nutritional components of traditional flours are dependent on the type of plant material used and to the extent it is milled and blended with other plant material. Generally speaking, a high protein cereal grain will result in a high protein flour, and increasing the metabolizable carbohydrate level in a raw material results in a final milled product with a similar metabolizable carbohydrate level.

Typical calorific levels for commonly used flours range from around 330 - 360 calories/100g for wheat, corn and rice flours, with nut based flours (for example, almond) reaching up to 550 – 600 calories per 100g. For consumers who are reducing their calorie intake for health or personal reasons, the relatively high calorie content of traditional flours makes them less desirable than other lower calorie food.

US200690280753 ('753) describes a "mycoflour" product produced from the fermentation of oats, the flour irradiated with UV light to increase the nutritional value of the flour, in particular vitamin D levels. The flours described within '753 however are high in metabolizable carbohydrate and are designed to provide an odourless, tasteless, calorie rich product that can be used as a food product.

US20100316763 ('763) describes a fermented food product made from edible plants or animals that can inhibit food deterioration and growth of pathogenic microbes in the food products. The food compositions include the addition of a saccharide and discloses the advantages of increasing carbohydrate, rather than providing any method or suggestion of the production of a low calorie food product.

US2006233864 discloses methods for improving the nutritional quality of fibrous by-products using fermentation, particularly to produce high protein feed for animals that will result in body weight gains by developing a feed having optimum levels of protein, fibre and fat for livestock.

It would be advantageous to develop a reduced calorie flour product for human consumption that could be incorporated into baked, processed or raw foods that retained the physical advantages of flour, without the high calorie content.

It would be a further advantage to produce flour composition low in metabolizable carbohydrate that provides an appealing range of tastes, textures and colours that can be utilized to achieve palatable food products.

It would be a further advantage to develop a process for the production of a low calorie flour that enabled the use of a wider range of plant materials than are commonly used to produce traditional flours.

It would be a further advantage to develop a useful food product from waste or by-products of fruit, vegetable or grain processing.

Object of the Invention

It is an object of the invention to provide a flour composition having less metabolizable carbohydrate when compared to other flours.

Alternatively, it is an object of the invention to provide a flour composition having a lower calorific value when compared to other flours.

Alternatively, it is an object to provide a process for the production of a flour composition having less metabolizable carbohydrate when compared to other flours.

Alternatively, it is an object to provide a process for the production of a flour composition having a lower calorific content when compared to other flours.

Alternatively, it is an object of the invention to provide a food composition derived from fungal fermentation of plant material, the food composition having a total metabolizable carbohydrate level less than the total metabolizable carbohydrate level of the plant material prior to fermentation.

Alternatively, it is an object of the invention to at least provide the public with a useful choice.

Summary of the Invention

According to a first aspect of the invention, there is provided a flour composition derived from fungal fermentation of plant material, the flour composition having a total metabolizable carbohydrate level of between 0.1 – 50% by weight.

In preferred embodiments of the invention, the flour composition comprises 0.1 – 30% by weight metabolizable carbohydrate. More preferably, the flour composition comprises 0.1 – 15% by weight metabolizable carbohydrate, even more preferably, less than 10% by weight available carbohydrate.

In further preferred embodiments of the invention the flour composition comprises between 30 – 90% by weight dietary fibre (non-metabolizable carbohydrate). In the more preferred embodiments, the flour comprises 40 – 80% by weight dietary fibre.

In more preferred embodiments, the dietary fibre includes 5% - 70% beta glucans, even more preferably, fungal derived 1, 3 and 1, 6 beta glucans. More preferably, the dietary fibre includes 40% - 65% fungal derived 1, 3 and 1, 6 beta glucans.

In further preferred embodiments the flour composition has 150 – 300 calories/100g flour.

More preferably, the flour composition includes 150 – 250 calories/100g flour.

In preferred embodiments the flour composition has less than 300 calories per 100g flour.

In preferred embodiments, the flour composition includes 0.1-15% metabolizable carbohydrate, 15 – 35% protein, 1 – 10% fat and 50 -80% dietary fibre.

More preferably, the dietary fibre includes 40% - 65% fungal derived 1, 3 and 1, 6 beta glucans.

In preferred embodiments of the invention the flour composition has a linoleic acid content of 10% of the total fat or greater.

More preferably, the flour composition has a linoleic acid content of 20-70% of the total fat.

In further preferred embodiments of the invention the plant material is selected from one or more fruits, nuts, cereals or vegetables including but not limited to kiwifruit, apple, pear, orange, carrot, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, chickpea, chia, grape, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, oats, cattails, quinoa, wheat, barley, buckwheat, corn, rice, atta, spelt, rye, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

In some embodiments of the invention the flour composition is gluten-free and the plant material is selected from one or more gluten free plant materials including, but not limited to kiwifruit, apple, pear, orange, carrot, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, grape, chickpea, chia, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, cattails, quinoa, buckwheat, corn, rice, atta, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

In some preferred embodiments, the plant material is derived from low starch fruit or vegetables including one or more of kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, onion, beetroot, banana, peach, nectarine, paw, pineapple, melon, watermelon, coconut, soybean or by-products and/or derivatives thereof such as pomaces, skins/peels, seeds or roots.

Preferably, the plant material contains less than 10% starch, more preferably, less than 5% starch and even more preferably, less than 2% starch.

In some preferred embodiments of the invention the composition includes 5 - 50% w/w of fungal biomass.

The flour composition of the present invention preferably has a flour whiteness similar to or darker than wheat flour.

According to a further aspect of the invention, there is provided a food composition derived from fungal fermentation of a low starch plant material having less than 20% w/w starch, the food composition having a total metabolizable carbohydrate level less than the total metabolizable carbohydrate level of the plant material prior to fermentation.

More preferably, the total metabolizable carbohydrate level of the food composition is at least 20% - 90% less than the total metabolizable carbohydrate level of the plant material prior to fermentation.

Even more preferably, the total metabolizable carbohydrate level of the food composition is at least 40% - 85% less than the total metabolizable carbohydrate level of the plant material prior to fermentation.

Preferably, the plant material contains less than 10% starch, more preferably, less than 5% starch and even more preferably, less than 2% starch.

In preferred embodiments of the invention the food composition is a paste, liquid, powder, solid, or in free-flowing form such as flakes, granules, grains or pellets.

According to a further embodiment of the invention there is provided a process for the production of a flour composition derived from fungal fermentation of plant material, the flour composition having a total metabolizable carbohydrate level of between 1 – 50% by weight, the process including the steps of;

a) hydrating, drying or maintaining a lignocellulosic plant material substrate to achieve a substrate moisture level between 45% – 95%;
b) sterilising the substrate of a);
c) inoculating the substrate with an active, edible higher fungus;
d) incubating the inoculated substrate for a period of time to produce a fermented substrate;
e) drying the fermented substrate; and
f) milling the dried, fermented substrate to form a flour composition.

More preferably, the process is for the production of producing a flour composition having a total metabolizable carbohydrate level of 0.1-15% by weight, and even more preferably, 5 - 10% by weight available carbohydrate.

Preferably, the active fungus used for inoculation in step c) is added at an amount of 5-50% w/w of the hydrated lignocellulosic plant material.

More preferably, the active fungus is added at an amount of 10-20% w/w.

In preferred embodiments of the invention, the process includes the further step of adding a functional additive to the substrate prior to inoculation. More preferably, the functional additive is a food grade nitrogen source. The nitrogen source is preferably selected from ammonium sulphate, glutamic acid, yeast extract, peptone and/or di-ammonium phosphate (DAP).

In further preferred embodiments of the invention the plant material is lignocellulosic plant material selected from one or more fruits, nuts, cereals or vegetables including but not limited to kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, chickpea, chia, grape, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, oats, cattails, quinoa, wheat, barley, buckwheat, corn, rice, atta, spelt, rye, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

In some embodiments of the invention the flour composition produced by the process described above is gluten-free and the plant material is lignocellulosic plant material selected from one or more gluten free plant materials including, but not limited to kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, grape, chickpea, chia, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, cattails, quinoa, buckwheat, corn, rice, atta, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

In some preferred embodiments, the plant material is derived from low starch fruit or vegetables including one or more of kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, onion, beetroot, banana, peach, nectarine, paw, pineapple, melon, watermelon, coconut, soybean or by-products and/or derivatives thereof such as pomaces, skins/peels, seeds or roots.

Preferably, the raw plant material contains less than 10% starch, more preferably, less than 5% starch and even more preferably, less than 2% starch.

In preferred embodiments of the invention the lignocellulosic plant material may be in the form of a moist or wet pomace, slurry, pulp or paste. Alternatively, the plant material may be in a dry or semi-dry form, such as a mulch, powder, or coarsely chopped plant material.

In further preferred embodiments, the step of hydrating, drying or maintaining the plant material achieves a substrate with a moisture content of between 75% - 90%, more preferably about 77% - 83%.

Preferably, the sterilisation step includes one or more of high temperature sterilisation, high pressure sterilisation, low temperature sterilisation, irradiation or chemical sterilisation.

In preferred embodiments of the invention the active edible, higher fungus utilised in the inoculation step are wood-decay fungi, and more preferably, white rot fungi or brown rot fungi.

In one preferred process where white rot fungi is used, the white rot fungi may be selected from the genera *Pleurotus*, *Lentinula, Ganoderma, Volvariella*, *Auricularia*, *Armillaria*, *Flammulina*, *Pholiota*, *Tremella* and/or *Hericium*.

In alternative process where brown rot fungi is utilised, preferred brown rot fungi may be selected from the genera *Agaricus*, *Laetiporus* and/or *Sparassis*.

Preferably, the incubation step includes incubating the inoculated substrate at 18°C – 40°C. More preferably, the incubation occurs at 25-30°C.

Preferably, the incubation period is 5 – 50 days. More preferably, the incubation period is 5 – 28 days.

In some preferred embodiments, the process includes incubating the inoculated substrate at 25°C for 30 days.

In preferred embodiments of the invention, the flour composition produced by the process comprises 0.1 – 30% by weight metabolizable carbohydrate. More preferably, the flour composition produced by the process comprises 0.1 – 15% by weight metabolizable carbohydrate, even more preferably, less than 10% by weight metabolizable carbohydrate.

In further preferred embodiments of the invention the flour composition produced by the process comprises between 30 – 90% by weight dietary fibre. In the more preferred embodiments, the flour comprises 40 – 80% by weight dietary fibre.

In more preferred embodiments, the dietary fibre includes 5% - 70% beta glucans, even more preferably, fungal derived 1-3 and 1-6 beta glucans.

More preferably, the dietary fibre includes 40% - 65% fungal derived 1, 3 and 1, 6 beta glucans.

In further preferred embodiments the flour composition produced by the process has 150 – 300 calories/100g flour. More preferably, the flour composition includes 150 – 250 calories/100g flour.

In even more preferred embodiments, the flour composition produced by the process has less than 200 calories per 100g flour.

In preferred embodiments of the invention the flour composition produced by the process has a linoleic acid content of 10% of total fat or greater.

In preferred embodiments of the invention the flour composition produced by the process has a linoleic acid content of 20-70% of total fat.

In a preferred embodiment of the invention the step of drying the fermented substrate includes drying the substrate at a temperature of 30° – 70°C. More preferably, the drying step occurs under vacuum conditions.

According to a further embodiment of the invention there is provided a process for the production of a composition derived from fungal fermentation of plant material, the composition produced by the process having a total metabolizable carbohydrate level of less than the total metabolizable carbohydrate level of the starting plant material, the process including the steps of;

a) hydrating, drying or maintaining a lignocellulosic plant material substrate to achieve a substrate moisture level between 45% – 95%;
b) sterilising the substrate of a);
c) inoculating the sterile substrate with an active, edible, higher fungus; and
d) incubating the inoculated substrate for a period of time to produce a fermented substrate.

Preferably, the active fungus used for inoculation in step c) is added at an amount of 5-50% w/w of the hydrated lignocellulosic plant material.

More preferably, the active fungus is added at an amount of 10-20% w/w.

In preferred embodiments of the invention the active, edible fungus utilised in the inoculation step are wood-decay or lignocolous fungi, and more preferably, white rot fungi or brown rot fungi.
In one preferred process where white rot fungi is used, the white rot fungi may be selected from the genera *Pleurotus*, *Lentinula, Ganoderma, Volvariella*, *Auricularia*, *Armillaria*, *Flammulina*, *Pholiota*, *Tremella* and/or *Hericium*.

Preferably, the process includes the further step of drying or partially drying the fermented substrate.

In one embodiment the fermented substrate is partially dried to form a paste.

In a further embodiment, the fermented substrate is dried to form a free-flowing composition. The free-flowing composition may be in the form of granules, powder, flakes, pellets or grains.

In further embodiments the fermented substrate is dried in a solid form or shape such as sheets, cubes, rolls or in specific three dimensional shapes, such as plates, cups, cup holders or packaging for example.

Throughout the specification the terms "metabolizable carbohydrate" and "total carbohydrate" are used. "metabolizable carbohydrate" represents that fraction of carbohydrate that can be digested by human enzymes, is absorbed and enters into intermediary metabolism. It does not include dietary fibre and for the purposes of this specification is calculated as:

Total carbohydrate – dietary fibre = metabolizable carbohydrate

The term "flour" or "flour composition" should be taken to mean any powder-like material produced by any means, and includes, but is not intended to be limited to powders produced solely by using milling techniques. "Flour composition" is intended to demonstrate the composition has one or more qualities similar to that of traditional flours, such as colour, texture, density, moisture levels or possible use for example.

Further aspects of the invention, which should be considered in all its novel aspects, will become apparent to those skilled in the art upon reading of the following description which provides at least one example of a practical application of the invention.

Brief Description of the Drawings

One or more embodiments of the invention will be described below by way of example only, and without intending to be limiting, with reference to the following drawings, in which:

Figure 1 shows the process for preparing a flour composition in one embodiment of the invention; and

Figure 2 shows a process for preparing a food composition in an alternative embodiment of the invention.

Detailed Description of Preferred Embodiments of the Invention

The composition and process of the present invention provides a range of low calorie flours and food compositions produced by the fermentation of lignocellulose-rich plant materials using edible higher fungi.

The fermentation of plant materials using fungi works on the principle that the fungi utilise the plant material as a food source to enable growth. When fermentation conditions are optimised to convert metabolizable sugars into protein-rich fungal biomass, the plant material substrate becomes depleted in energy after fermentation, particularly metabolizable carbohydrates. This can result in a substrate having a lower calorific value and higher protein content than prior to the fermentation process.

The fermented flour products produced are low in metabolizable carbohydrates, fat, cholesterol and may be gluten free, while being high in dietary fibre, particularly beta-glucan prebiotic fibre, and protein. These characteristics make them particularly attractive for creating lower calorie baked goods, as well as having other applications as pet food, nutraceutical, cosmetic or pharmaceutical ingredients or for other non-food purposes. The flour compositions described herein impart a range of different flavours, textures and colours to food products depending on the plant material used in the production process, making then a valuable ingredient in a wide range of food products.

The flours and flour blends of the present invention may be derived from a wide variety of fruits, vegetables, nuts and grains. One of the advantages of the present invention is that the preparation process involves the use of a high-water content substrate, as opposed to the dry plant material that is commonly used in the flour milling process. This ability to use a wet substrate increases the range of plant materials that may be used to create a flour composition, for example fresh whole or waste fruit, pomaces, peels or other by products from separate industrial processes such as juicing. The process enables the use of by-products from the agriculture and food production industry to produce a nutritious food product suitable for human consumption.

In the preferred embodiment of the invention the food composition is milled to create a flour. However, the process may also be used without milling to create a fermented food composition in the form of a free-flowing material such as flakes, granules, pellets or grains. Alternatively the fermented food product may be formed into solid 3D shapes or sheets, or only partially dried to create a paste or liquid product.

In one preferred embodiment of the invention where the food composition is a flour composition, the plant material used as a substrate for flour production is apple pomace, typically sourced as a by-product from the juicing industry. Similar pomaces often obtained as juicing by-products that are exemplified below are carrot pomace and orange pomace. These substrates are given as examples only and are not intended to be limiting. It is envisaged that a wide range of fruits, vegetables, cereals and parts thereof may be used in the preparation of a low calorie flour composition. The process described below can be implemented on plant material having a wide variety of textures, sizes and moisture content, from dry cereal grains through to wet waste material formed as a by-product of other fruit or vegetable processing operations.

As described earlier, some of the plant material that may be suitable for the flour compositions of the present invention are fruits, nuts, cereals or vegetables including but not limited to kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, chickpea, chia, grape, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, oats, cattails, quinoa, wheat, barley, buckwheat, corn, rice, atta, spelt, rye, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

In preferred embodiments of the invention, the plant material is derived from low starch fruit or vegetables which including one or more of kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, onion, beetroot, banana, peach, nectarine, paw, pineapple, melon, watermelon, coconut, soybean or by-products and/or derivatives thereof. Low starch product as particularly suited for the production of the compositions of this invention, as when processed according to the disclosed methods, a flour composition having low levels of metabolizable carbohydrate can be achieved.

Preferably, the plant material contains less than 10% starch, more preferably, less than 5% starch and even more preferably, less than 2% starch.

The fermentation step in the process of the present invention involves the use of edible higher fungi to break down the plant material and digest the carbohydrate present within the substrate. When the resulting flour composition is to be used for human consumption edible fungi should be used to ensure the flour composition product is non-toxic and meets appropriate food standards and regulations. In some instances the flour compositions of the present invention may be used for non-food purposes, for example as an adhesive, binder, filler, biofuels, cosmetics or depending on the substrate used, as a biodegradable substitute for polystyrene and other plastics, such as in disposable plates and cutlery, or as packaging inserts. Depending on the situation for which the flour composition is to be used, non-edible fungi or fungi that imparts an unpleasant taste may be utilised if suitable.

Basidiomycota and *Ascomycota* are two large fungal phyla that constitute the subkingdom *Dikarya*, which is often referred to as the "higher fungi" within the kingdom Fungi. These include “wood decay” fungi that are characterised by their ability to digest lignocellulosic materials - also known as lignocolous fungi, which includes both brown-rot and white-rot fungi. This ability of lignocolous fungi to grow on the plant material and actively digest lignocellulosic material is allows for the fermentation of plant materials to successfully produce the flour compositions of the present invention.

Lignocellulose is a complex mixture of plant cell wall polymers composed mainly by polysaccharides (e.g. cellulose and hemicellulose) and aromatic lignin polymer. Together with pectin and starch, these are the main components of plant dry matter. White-rot fungi break down the lignin in plant material, leaving the lighter-coloured cellulose behind, giving to the plant material a whitish colour. The use of such white rot fungi in the present invention help to achieve a final flour composition with a whiter, more appealing colour.

Non-limiting examples of edible white rot fungi that may be used with the current process are fungi from the genus *Pleurotus* (e.g. *P. ostreatus, P. eryngi, P. pulmonarius, P. djamor, P. australis, P. purpureo-olivaceus, P. citrinopileatus, P. sajor-caju, P. florida, P. flabellatus, P. ferulae, P. cystidiosus*), *Lentinula* (*L. edodes, L. boryana, L. novae-zelandiae, L. tigrinus*), *Ganoderma* (*G. lucidum, G. applanatum, G. tsugae*), *Volvariella* (*V. volvacea, V. esculenta, V. bakeri, V. dysplasia*), *Auricularia* (*A. auricola, A. cornea, A. subglabra*), *Armillaria (A. mellea, A. ostoyae, A. gemina, A. calvescens, A. Sinapin, A. gallica*), *Flammulina* (*F. velutipes, F.* fennae), *Pholiota (P. squarrosa, P. nemako*), *Tremella* (*T. mesenterica*, *T. fuciformis*), *Hericium* (*H. erinaceus*, *H. coralloides*) among others.

A further type of fungi that may be utilised in the current process are known as brown-rot fungi. Brown rot fungi preferentially break down hemicellulose and cellulose in plant matter. As a result of this type of decay, the plant material shows a brownish discoloration, which may result in a final flour composition having a darker colour than a flour produced using the fermentation of a white rot fungi. Examples of edible brown rot fungi are species belonging to the genus *Agaricus (A. campestris, A. bisporus, A. bitorquis*), *Laetiporus* (*L. sulphurous*), *Sparassis* (*S. crispa*, *S. spathulata*).

Fungal cultures suitable for use in the present invention may be purchased from a wide range of specialist retailers selling mushroom and fungal supplies, for example the website www.fungi.com retails a wide range of different fungal cultures at the time of writing. Alternatively, the fungal cultures may be isolated directly from mushrooms themselves, for example oyster mushrooms may be used to supply inoculant of *Pleurotus pulmonarius,* Portobello or button mushrooms may be used to supply inoculant of *Agaricus* species.

The selection of using brown rot and/or white rot fungi may be influenced by the desired colour of the final product or by the characteristics of the substrate. For example a particularly fibrous substrate may be fermented using a combination of both a white rot and a brown rot fungi in order to aid in the digestion of the high levels of lignin, cellulose and hemicellulose.

The use of higher fungi, such as the brown and white rot fungi, in the process of the present invention is indicated by the presence of linear (1,3)-beta-glucans with (1,6)-linked-beta-glucosyl or beta-(1,6)-oligoglucosyl side chains in the final fermented product. The use of other fungi for the fermentation process, such as yeast and imperfect fungi, would result in the final composition having the presence of branch-on-branch (1,3; 1,6)-beta-glucans, for example. These differences enable the type of fungi used in the process to be determined by analysis of the final flour product.

A diagrammatic representation of the process used to produce the food compositions of the present invention is shown in Figure 1 by process 100 and Figure 2 by process 200. The process of Figure 1 shows the steps required to make a flour composition, while Figure 2 outlines the process for making a food composition that may take a variety of different structural forms.

In a first step 10 of the process 100, raw lignocellulosic plant material is obtained. The selection of the type of plant material to be used will be dependent on the end product use. For the production of a low-calorie gluten free flour to be used in baking or as an additive in commercial food production, a gluten-free plant material, such as a fruit or vegetable derived plant material would be used.

In order to prepare the substrate for fermentation, the substrate is prepared such that is has a moisture content of between approximately 55% and 90%. This preparation step may include the hydration of the substrate by the addition of water if the plant material has a lower moisture content than required, or in some circumstances drying, pressing or decanting may be required if a particularly wet substrate is used. For substrates that are obtained already having a moisture level within the required ranges, such as a fruit pomace, no further hydration or drying is required.

For particularly dry substrate the hydration process may include adding additional amounts of water to the substrate over a period of time to ensure the water has been fully absorbed within the plant material before progressing to the next step in the process.

Once the substrate has been prepared, the substrate is sterilised 30. This step may occur using standard heat and high pressure sterilisation to kill microbes, or other sterilisation methods such as irradiation, low temperature sterilisation or chemical sterilisation if appropriate to the end product use.

During the substrate preparation steps, functional additives may optionally be added to the substrate to fortify the product or to increase particular levels of certain substances within the substrate. In one example it may be beneficial to decrease the carbon/nitrogen ratio of the substrate through supplementation with inorganic or organic food grade nitrogen sources. Examples of such sources include, but are not limited to ammonium sulphate, glutamic acid, yeast extract, peptone, di-ammonium phosphate (DAP).

Following sterilisation the substrate is cooled to room temperature and inoculated with fungal culture 40. The fermentation process relies on the use of active fungal biomass as inoculant to be used to colonise the sterile plant material substrate. Preferably, approximately 5% – 50% (w/w wet substrate) of actively growing fungal culture is used to effectively inoculate the entire substrate. Once the fungal culture has been added to the substrate, it is mixed through the substrate, preferably uniformly and the substrate is then ready for incubation 50.

The use of fungal substrate in an amount of 5-50% w/w of the plant material is preferable, with more preferred amounts of fungal substrate added being in the range of 10-20% w/w. The final amount of fungal substrate used will depend on the type of lignocellulosic plant material being used, however levels above at least 5% w/w fungal substrate has been shown to result in the composition of the present invention with lower levels of metabolizable carbohydrate within a shorter period of time to known fermentation techniques.

Incubation 50 of the inoculated substrate under sterile conditions takes place over a period of anywhere from 5 – 50 days, but preferably between 5-28 days. Complete colonisation is judged using visual analysis, although it is expected that different type of fungi and substrate combinations may increase or decrease the incubation period. The ability of the process of the present invention to achieve the low carbohydrate composition of the present invention using less than four weeks of fermentation time results in a number of efficiencies economically, including reduced storage time, reducing processing costs and allowing for greater production capacity when compared with extended fermentation cycles.

Temperature and humidity conditions during incubation are very important. Optimum temperatures for fungal growth are between 18°C - 30°C, with temperatures above 30°C slowing fungal growth and temperatures above 40°C resulting in very little fungal growth. Maintaining temperatures at 25-30°C is particularly preferable to produce the flour compositions of the present invention, within an economically beneficial timeframe.

Specific optimum temperatures exist for different fungi species and these should be taken into consideration when the incubation conditions are set up. Humidity in the incubation space should be kept to a maximum to facilitate fungal growth, preferably between 90 – 100% humidity.

Air flow around the substrate during incubation should also be managed to prevent build-up of either excessive oxygen or carbon dioxide. CO_2 levels are preferably held between 5 and 30% for the *Pleurotus* fungi, however this may change depending on the fungi used in the fermentation process.

During growth, the fungus consume free sugars and degrade plant polymers in the substrate, converting them into a biomass rich in proteins, fungal polysaccharides (chitin and β-1,3 and β-

1,6-glucans), and fungal-derived vitamins. This consumption of sugars results in the low calorie/low metabolizable carbohydrate flour composition formed in the final stages of the process.

Following incubation, the fermented substrate is removed from incubation and dried 60 using a low temperature drying process. The drying process may be undertaken using commonly known drying apparatus, such as food desiccation apparatus, air drying, drum drying or oven drying. Preferably, the drying temperature is kept below 40°C as the lower temperature drying has been found to achieve an end product with a lighter colour, making it more preferable for some baked products. When the end product is to have a use where the final product colour is less important, the drying temperature may be increased to speed up the drying process. The maximum drying temperature should be around 75°C, as at temperatures higher than this the nutritional value of the composition can be compromised by the breakdown of antioxidants, vitamins or proteins for example.

The drying of the fermented substrate may occur under vacuum conditions. This may result in a product having a lighter or whiter final colour and milder flavour compared to not drying under vacuum, possibly due to the decreased oxidation of the composition during the drying process and reduction of aroma compounds through vacuum.

The colonised substrate is dried until it becomes millable, usually when the moisture content is less than or close to 14%. At moisture levels above 14%, microorganisms can begin to flourish, affecting the taste, aroma and shelf life of the product.

Subsequently the dry substrate is milled 70 into a fine flour, using standard milling techniques. The dry substrate is composed of plant material components not metabolised by the fungus such as plant fibre, plant vitamins and minerals, combined with the dried fungal biomass.

The final dried, milled product produced as a result of this process is a lower calorie, low metabolizable carbohydrate flour when compared to flour produced using standard flour processing techniques. Three examples provided below show the process and final product produced using apple, carrot and orange pomaces.

Figure 2 shows process 200. The process 200 is essentially the same as the process 100 described above for Figure 1, however drying step 60 and milling step 70 have been omitted. Instead, in process 200 following incubation step 160, the process is dried or partially dried 170. The drying may result in a food composition having a range of different textures, sizes and shapes depending on how the drying takes place, and the extent to which drying occurs.

The drying step 170 may include the use of know techniques for the drying or partial drying of a wet substrate to form various shapes and textures. For example, the substrate may be dried in thin layers to produce a flaked product, compacted and dried simultaneously to produce a solid form, dried and densified to produce pellets, or partially dried and blended to produce a paste.

EXAMPLE 1 – Apple Flour

Wet apple pomace (80% w/w moisture) was mixed with a 1% (w/w) food grade yeast extract in 1-3kg batches. The mixture was heat-sterilised at a pressure of 100 kPa (15 psi), and 121°C for 20 minutes.

The substrate was cooled to room temperature then 10% (w/w) of fungal inoculant consisting of actively growing culture of *Pleurotus pulmonarius* was aseptically added.

The substrate and inoculant were mixed uniformly and the inoculated substrate incubated under sterile conditions for 30 days at 25°C, allowing air exchange between the culture and environment, but retaining maximum humidity.

After incubation, the fermented substrate was removed from the incubators and the contents dried using a food desiccator at 35°C, to achieve a moisture content below 14%.

The dry fermented material was then passed through an appropriate mill to produce a fine flour.

The composition of the final product is given below showing the composition of individual macro and micronutrients per 100g.

Compositional Analysis of Exemplary Fermented Apple Flour	
	Per 100 grams
Moisture at 105°C	6.9 g
Energy	960 KJ (229.4 cal)
Protein[§]	20 g
Fat	4.1 g
Saturated fat	0.6 g
Linoleic acid	1.5 g
Oleic acid	0.6 g
Cholesterol	<12 mg
Carbohydrate (corrected by TDF)	8.0 g
Soluble sugars	2.7 g
Total dietary fibre (TDF)	58.4 g
β-1,3 and β-1,6 glucan fibre	24.8 g
Ash	2.0 g
Sodium	140.0 mg
Potassium	628.1 mg
Calcium	230.0 mg
Phosphorus	118.8 mg
Magnesium	72.2 mg
Iron	5.5 mg
Zinc	2.0 mg
Selenium	5.0 mcg
Vitamin A (as retinol)	<0.50 mg
Vitamin D	<0.20 mg
Vitamin E	0.52 mg

The process exemplified in Example 1 for the production of apple flour was replicated using *Lentinula edodes*, an alternative species of white-rot fungi. The results comparing the final flour compositions produced using the different fungi are shown below:

Chemical composition of apple flour fermented by two different white-rot fungi

Per 100g	***Pleurotus pulmonaris***	***Lentinula edodes***
Protein (g)	20.0	24.0
Carbohydrate (corrected by TDF)	8	5.3
Soluble sugars (g)	2.7	0.3
Dietary fibre (g)	58.4	55.6
Fat (g)	4.1	5.3

EXAMPLE 2 – Carrot Flour

1-3 kg batches of carrot pomace were heat-sterilised at a pressure of 100 kPa (15 psi), and 121°C for 20 minutes.

The substrate was cooled to room temperature then 10% (w/w) of fungal inoculant consisting of actively growing culture of *Pleurotus pulmonarius* was aseptically added.

The substrate and inoculant were mixed uniformly and the inoculated substrate incubated under sterile conditions for 30 days at 25°C, allowing air exchange between the culture and environment, but retaining maximum humidity.

After incubation, the fermented substrate is removed from the incubators and the contents dried using a food desiccator at 35°C, to achieve a moisture content below 14%.

The dry fermented material was then passed through an appropriate mill to produce a fine flour.

Compositional Analysis of Exemplary Fermented Carrot Flour	
	Per 100 grams
Moisture at 105°C	7.0 g
Energy	831 KJ (198.6 cal)
Protein[§]	17 g
Fat	0.2 g
Saturated fat	<0.1 g
Linoleic acid	0.14 g
Oleic acid	0.02 g
Cholesterol	<12 mg
Carbohydrate (corrected by TDF)	7.9 g
Soluble sugars	1.7 g
Total dietary fibre (TDF)	63.2
β-1,3 and β-1,6 glucan fibre	39.5 g
Ash	3.8 g
Sodium	300 mg
Potassium	2253.5 mg
Calcium	829.5 mg
Phosphorus	258.6 mg
Magnesium	141.8 mg
Iron	14.5 mg
Zinc	2.4 mg
Selenium	5.2 mcg
Vitamin A (as retinol)	<0.5 mg
Vitamin D	<0.2 mg
Vitamin E	<0.5 mg

The process exemplified in Example 2 for the production of carrot flour was replicated using *Lentinula edodes*, an alternative species of white-rot fungi. The results comparing the final flour compositions produced using the different fungi are shown below:

Chemical composition of carrot flour fermented by two different white-rot fungi

Per 100g	***Pleurotus pulmonaris***	***Lentinula edodes***
Protein (g)	17.0	13.1
Carbohydrate (corrected by TDF)	7.9	9
Soluble sugars (g)	1.7	0.8
Dietary fibre (g)	63.2	67.1
Fat (g)	0.2	0.3

EXAMPLE 3 – Orange Flour

1-3 Kg batches of wet orange pomace were heat-sterilised at a pressure of 100 kPa (15 psi), and 121°C for 20 minutes. The substrate was cooled to room temperature then 10% (w/w) of fungal inoculant consisting of actively growing culture of *Pleurotus pulmonarius* was aseptically added.

The substrate and inoculant were mixed uniformly and the inoculated substrate incubated under sterile conditions for 30 days at 25°C, allowing air exchange between the culture and environment, but retaining maximum humidity.

After incubation, the fermented substrate is removed from the incubators and the contents dried using a food desiccator at 35°C, to achieve a moisture content below 14%.

The dry fermented material was then passed through an appropriate mill to produce a fine flour.

Compositional Analysis of Exemplary Fermented Orange Flour

Per 100 grams

Moisture at 105°C	7.5 g
Energy	896 KJ (214.1 cal)
Protein§	20 g
Fat	0.9 g
Saturated fat	0.3 g
Linoleic acid	0.5 g

Oleic acid	0.15 g
Cholesterol	<12 mg
Carbohydrates	12.9 g
Soluble sugars	3.3 g
Total dietary fibre	55.0 g
β-1,3 and β-1,6 glucan fibre	22.9 g
Ash	4.3
Sodium	290.0 mg
Potassium	1060.4 mg
Calcium	1106.5 mg
Phosphorus	122.9 mg
Magnesium	106.1 mg
Iron	2.5 mg
Zinc	2.2 mg
Selenium	6.0 mcg
Vitamin A (as retinol)	<0.50 mg
Vitamin D	<0.20 mg
Vitamin E	<0.50 mg

The process exemplified in Example 3 for the production of orange flour was replicated using *Lentinula edodes*, an alternative species of white-rot fungi. The results comparing the final flour compositions produced using the different fungi are shown below:

Chemical composition of orange flour fermented by two different white-rot fungi

Per 100g	***Pleurotus pulmonaris***	***Lentinula edodes***
Protein (g)	20.0	17.6
Carbohydrate (corrected by TDF)	13.0	10.9
Soluble sugars (g)	3.3	1.2
Dietary fibre (g)	55.0	57.8
Fat (g)	0.9	1.1

Tables 1 and 2 below shows a nutrient comparison of substrates before and after fermentation, and provides results for the fermentation of additional plant material, grape, beetroot and kiwifruit.

Table 1

	Apple by-product fermentation		**Orange by-product fermentation**		**Carrot by-product fermentation**	
	before	after	before	after	before	after
Energy (cal)	335	229	346	214	354	199
Protein (%)	4	20	4	20	6	17
Carbs (%)	44	3	33	3	11	2
Dietary fiber (%)	29	58	23	55	32	63
Total fat (%)	4	4	2	1	1	0
Beta-glucans (%)	0	25	0	23	0	40
Calcium (mg)	90	230	475	1106	485	830
Potassium (mg)	419	628	645	1060	1390	2254
Iron (mg)	3.7	5.5	1.7	2.5	3.9	14.5
Zinc (mg)	1.1	2	1.3	2	1.6	2.4

Table 2

	Grape by-product fermentation		**Beetroot by-product fermentation**		**Kiwifruit by-product fermentation**	
	before	after	before	after	before	after
Energy (cal)	224	178	323	158	138	118
Protein (%)	8	23	11	20	8	15
Carbs (%)	29	1	42	2	17	2
Dietary fiber (%)	46	63	17	65	67	69
Total fat (%)	8	8	1	3	4	2

Beta-glucans (%)	0	*	0	*	0	*
Calcium (mg)	411	620	133	349	*	360
Potassium (mg)	1200	12270	2697	3100	*	1680
Iron (mg)	7.9	11.9	6.6	9.8	*	2.7
Zinc (mg)	1.3	1.9	2.9	6	*	1.9

As shown by the tables above, the fermentation process significantly reduces the amount of metabolizable carbohydrate present in the final flour composition when compared to the original fruit/vegetable pomace. The total simple sugar level in each of the flour compositions has reduced significantly following the fermentation process, with the total metabolizable carbohydrate of the final fermented product being 18% of the apple pomace (or a 82% reduction in total carbohydrate).

Similar reductions can be seen in the carrot flour, which shows a 41% reduction in metabolizable carbohydrate in the final product compared to the pomace and orange flour, which shows a 61% reduction in total metabolizable carbohydrate compared with the raw orange pomace. Similar reductions in metabolizable carbohydrate are shown to be achieved with grape, beetroot and kiwifruit pomace.

The reduction in metabolizable carbohydrate level between the starting plant material and the final product may vary between plant materials, however it is expected that most plant materials will have a 20% - 90% reduction, with the majority being reduced between 40% - 85% compared to the original starting material.

Each of the fermented flours are also shown to have increased in protein when compared to the raw pomace as a result of the fungal fermentation and maintained low levels of fat and very low levels of cholesterol.

Table 3 below shows the fermented flour examples compared to a selection of flours and fibres produced by standard non-fermentation techniques.

Table 3: Fermented flour v Standard flour comparison

Serving size: 100g		Calories (cal)	Fat (g)	Carbs (g)	Dietary fiber (g)	Protein (g)
Green Spot's Fermented Flours	**Apple flour**	**229**	**4**	**8**	**58**	**20**
	Orange flour	**214**	**1**	**13**	**55**	**20**
	Carrot flour	**199**	**0**	**8**	**63**	**17**
Traditional Flours	Wheat flour	364	1	73	3	10
	Oat flour	404	9	60	6	15
	Rice flour	366	1	80	2	6
Alternative Flours	Pea flour	306	2	48	18	22
	Garbanzo flour	387	7	47	11	22
	Montina flour	380	3	53	17	17
Functional (Specialty) Flours	Quinoa flour	396	5	58	7	14
	Chia flour	517	33	8	37	17
	Almond flour	144	12	2	2	6

Comparing the flour compositions of the present invention with traditional, alternative and functional flours a significantly reduced level of metabolizable carbohydrate can be clearly seen in each of the fermented flours. In addition, the fermented flours show similar or greater protein levels than all traditional flours and functional flours. Flours with higher protein content as pea and garbanzo flour, but they also show significantly higher levels of carbohydrate than the fermented flours. Comparison of the overall calorific content of each of the products per 100g shows the fermented flours having a lower energy loading than all of the flours with the exception of almond flour, making them an excellent option to produce low calorie food products.

The combination of the above characteristics results in product that is low in metabolizable sugars, low in fat, while high in protein and fibre, produced by a natural process. In preferred embodiments described within, the flour compositions include 0.1 - 15% metabolizable carbohydrate, 15 – 35% protein, 1 – 10% fat and 50 -80% dietary fibre. The inclusion of this range of qualities within a single flour product is a significant advantage commercially and nutritionally.

The fermented flour can be made gluten-free by selecting a gluten-free substrate and unlike other flours it presents very low levels of metabolisable sugars such as mono- and disaccharides and starch; and fat, which makes it a low energy food ingredient.

The colour of the fermented flour vary from alabaster-pearl white to a dark brown shade depending on the starting plant material and fungal species, which also influence the flour odour and taste.

The fermented flours have much potential for the use in the naturally healthy packaged food industry. In particular but not limited to snack or breakfast bars, which can be enriched with the protein, vitamins and dietary fibres of this inventive low calorie flours. Alternatively, the fermented flours can be incorporated into food during the baking and cooking process as a naturally nutritious flour or thickening agent, or it can replace completely or partially traditional flours (e.g. wheat, rye, rice, oat, etc.) in baking, pastries, and pastas; making these products suitable for the dieting, vegan and gluten-free markets as a low carb flour substitute.

Some examples of potential downstream applications for the use of the flour compositions of the present invention are provided below:

Fermented Orange Flour gluten-free biscuit

Ingredients:	**Grams**
Corn flour	220
Fermented orange flour	20
Margarine	140
White or brown sugar	50

Desiccated coconut	30

Instructions

Combine all dry ingredients.

Make a well in the centre of the dry ingredients and add margarine.

Mix on medium-low speed until well combined.

Make small balls and press it with a fork.

Bake the biscuits for 25 to 30 min at 300F

Fermented Apple Gluten-free Snack Bar

Ingredients:	**Grams**
GF rolled oat	70
Fermented apple flour	70
Almond butter	90
Chia seeds	20
Flax meal	15
Medjool dates pitted	15
Water	125

Instructions

Combine all dry ingredients. Mix until well combined.

Add almond butter and the water.

Spread evenly in a sheet pan and store in the fridge for 30 min. Cut in squares to serve.

Fermented Carrot Flour Pasta Dough

Ingredients:	**Grams**
Semolina flour	110
Whole wheat flour	55
Bread flour	55
Fermented carrot flour	16
Salt	1
Whole egg	One
Egg yolks	Five
Milk	22 ml

Instructions

Combine all dry ingredients.

Make a well in the center of the dry ingredients; add eggs, yolks and milk.

Mix on medium-low speed until well combined.

Once the dough is mixed, turn out onto a sheet of plastic wrap. Form dough into a ball, wrap tightly and let rest in the refrigerator for two (2) hours.

Once dough is chilled, divide in to four (4) even pieces. Depending on the type of pasta you want to make, use either a pasta roller or a rolling pin to create even sheets. Hand cut or continues using your pasta roller to achieve desired shape.

Pasta can either be used immediately or air-dried for future use.

Fermented Apple and Carrot Flours Barbeque Sauce

Ingredients:	**Grams**
Tomato sauce	425
Fermented apple flour	30
Fermented carrot flour	30
Apple cider vinegar	118 ml
Honey	170
Tomato paste	56
Molasses	85
Worcestershire	51
Mesquite liquid smoke	9 ml
Smoked paprika	1
Clove garlic	one
Black pepper	1
Onion powder	1
Salt	1

Instructions

In a blender, blend together all ingredients on low for 30 seconds until smooth.

In a medium saucepan, bring sauce to a simmer over medium heat. If the sauce appears too thick, add water until you reach your desired consistency.

Use the sauce immediately, or refrigerate in a sealed container for up to 1 week.

Fermented Apple Flour Russian Black Bread

Ingredients:	Grams
Lukewarm water	255
Apple cider vinegar	28
Fermented apple flour	169
Salt	7
Unsalted butter	28
Brown sugar	14
Fennel seeds	3 to 7
Instant yeast	7.5
Unbleached Bread Flour	298

Instructions

Place all of the ingredients in a large bowl, reserving 1 cup of the bread flour. Mix until sticky dough begins to form.

Mix in the remaining flour and knead for 7 minutes, or until the dough becomes soft and elastic, but may still be somewhat sticky to the touch. Cover the bowl and let the dough rise until doubled, 45 minutes to 1 hour.

After the first rise, shape the dough into an oblong loaf. Place in a greased 9" x 5" or 10" x 5" bread pan, cover with greased plastic, and let rise until almost doubled, about 60 to 90 minutes.

While the dough is rising, preheat the oven to 375°F. When the dough has almost doubled, brush or spray the top with water, dust with pumpernickel or fermented apple, and score (slash) the top.

Bake the bread for about 35 minutes, until it sounds hollow when you thump the bottom, or the inside measures 205°F on a digital thermometer. Remove the loaf from the oven and cool it on a rack before slicing.

Store bread well wrapped at room temperature for several days. Freeze for longer storage.

The fermented flours may also be formulated into naturally healthy food and beverage supplements, nutraceuticals and/or nutritional or pharmaceutical supplements.

The fermented flours of the present invention may have further application outside the food industry, as an ingredient in adhesive, industrial filler and binders, cosmetics, or used to create biodegradable packing, for example disposable cups, plates, cutlery or packing fillers and inserts.

The entire disclosures of all applications, patents and publications cited above and below, if any, are herein incorporated by reference.

Reference to any prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that that prior art forms part of the common general knowledge in the field of endeavour in any country in the world.

Where in the foregoing description reference has been made to integers or components having known equivalents thereof, those integers are herein incorporated as if individually set forth.

It should be noted that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. Such changes and modifications may be made without departing from the spirit and scope of the invention and without diminishing its attendant advantages. It is therefore intended that such changes and modifications be included within the present invention.

Claims

1. A flour composition derived from fungal fermentation of plant material, the flour composition having a total metabolizable carbohydrate level of between 0.1 – 50% by weight.

2. The flour composition of claim 1, wherein the flour composition comprises 0.1 – 30% by weight metabolizable carbohydrate.

3. The flour composition of claim 2, wherein the flour composition comprises 0.1 – 10% by weight metabolizable carbohydrate.

4. The flour composition of any one of claims 1 -3, wherein the flour comprises between 30 – 90% by weight dietary fibre.

5. The flour composition of claim 4, wherein the dietary fibre includes 10-70% beta glucans.

6. The flour composition of claim 5, wherein the beta glucans includes 40% - 65% fungal derived 1,3 and 1,6 beta glucans.

7. The flour composition of any one of claims 1 - 6, wherein the flour composition has 150 – 300 calories/100g flour.

8. The flour composition of any one of claims 1 - 6, wherein the flour composition has less than 200 calories per 100g flour.

9. The flour composition of claim 1 , wherein the composition includes 0.1-15% metabolizable carbohydrate, 15 – 35% protein, 1 – 10% fat and 50 - 80% dietary fibre.
10. The flour composition of claim 9, wherein the dietary fibre includes 40% - 65% fungal derived 1, 3 and 1, 6 beta glucans.

11. The flour composition of any one of claims 1 - 10, wherein the flour composition has a linoleic acid content of 10% of the total fat or greater.

12. The flour composition of claim 11, wherein the flour composition has a linoleic acid content of 20-70% of the total fat.

13. The flour composition of any one of claims 1 - 12, wherein the plant material is selected from one or more fruits, nuts, cereals or vegetables including but not limited to kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, chickpea, chia, grape, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, oats, cattails, quinoa, wheat, barley, buckwheat, corn, rice, atta, spelt, rye, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

14. The flour composition of any one of claims 1 - 12, wherein the flour composition is gluten-free and the plant material is selected from one or more gluten free plant materials including, but not limited to kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, grape, chickpea, chia, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, cattails, quinoa, buckwheat, corn, rice, atta, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

15. The flour composition of any one of claims 1 – 12, wherein the plant material is derived from low starch fruit or vegetables including one or more of kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, onion, beetroot, banana, peach, nectarine, paw, pineapple, melon, watermelon, coconut, soybean or by-products and/or derivatives thereof such as pomaces, skins/peels, seeds or roots.

16. The flour composition of claim 15, wherein the plant material contains less than 10% starch.

17. The flour composition of claim 16, wherein the plant material contains less than 2% starch.

18. The flour composition of any one of claims 1 - 17, wherein the composition includes5-50% w/w of fungal biomass.

19. A food composition derived from fungal fermentation of a low starch plant material having less than 20% w/w starch, the food composition having a total metabolizable carbohydrate level less than the total metabolizable carbohydrate level of the plant material prior to fermentation.

20. The food composition of claim 19, wherein the total metabolizable carbohydrate level of the food composition is at least 20% - 90% less than the total metabolizable carbohydrate level of the plant material prior to fermentation.

21. The food composition of claim 20, wherein the total metabolizable carbohydrate level of the food composition is at least 40% - 85% less than the total metabolizable carbohydrate level of the plant material prior to fermentation.

22. The flour composition of claim 19, wherein the plant material contains less than 10% starch.

23. The flour composition of claim 22, wherein the plant material contains less than 2% starch.

24. The food composition of any one of claims 19 – 21, wherein the food composition comprises between 30 – 90% by weight dietary fibre.

25. The food composition of claim 24, wherein the dietary fibre includes beta glucans.

26. The food composition of claim 25, wherein the dietary fibre includes 40% - 65% fungal derived 1,3 and 1,6 beta glucans.

27. The food composition of any one of claims 19 - 26, wherein the food composition is a paste, powder, liquid, solid, or in free-flowing form such as flakes, granules, grains or pellets.

28. A process for the production of a flour composition derived from fungal fermentation of plant material, the flour composition having a total available carbohydrate level of between 1 – 50% by weight, the process including the steps of;

a) hydrating, drying or maintaining a lignocellulosic plant material substrate to achieve a substrate moisture level between 45% – 95%;
b) sterilising the substrate of a);
c) inoculating the sterile substrate with an active, edible, higher fungus;
d) incubating the inoculated substrate for a period of time to produce a fermented substrate;
e) drying the fermented substrate of d); and
f) milling the dried, fermented substrate to form a flour composition.

29. The process of claim 28, wherein the process is for the production of producing a flour composition having a total metabolizable carbohydrate level of 0.1-15% by weight.

30. The process of claim 29, wherein the process is for the production of a flour composition having a total metabolizable carbohydrate level of 5 - 10% by weight.

31. The process of claim 28, wherein the active, edible, higher fungus used for inoculation in step c) is added at an amount of 5-50% w/w of the hydrated lignocellulosic plant material.

32. The process of claim 31, wherein the fungus is added at an amount of 10-20% w/w.

33. The process of claim 28, wherein the process includes the further step of adding a functional additive to the substrate prior to inoculation.

34. The process of claim 33, wherein the functional additive is a food grade nitrogen source.

35. The process of claim 34, wherein the food grade nitrogen source is selected from ammonium sulphate, glutamic acid, yeast extract, peptone and/or di-ammonium phosphate (DAP).

36. The process of any one of claims 28 - 35, wherein the plant material is lignocellulosic plant material selected from one or more fruits, nuts, cereals or vegetables including but not limited to kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, chickpea, chia, grape, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, oats, cattails, quinoa, wheat, barley, buckwheat, corn, rice, atta, spelt, rye, hemp, teff or by-products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

37. The process of any one of claims 28 - 35, wherein the flour composition produced by the process is gluten-free and the plant material is lignocellulosic plant material selected from one or more gluten free plant materials including, but not limited to kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, cassava, onion, parsnip, beetroot, banana, peach, nectarine, paw, pineapple, melon, mesquite, watermelon, acorn, hazelnut, chestnut, grape, chickpea, chia, potato, coconut, almond, soybean, sorghum, arrowroot, amaranth, taro, cattails, quinoa, buckwheat, corn, rice, atta, hemp, teff or by-

products and/or derivatives thereof such as fruit and vegetable pomaces, skins/peels, seeds or roots.

38. The flour composition of any one of claims 28-35, wherein the plant material is derived from low starch fruit or vegetables including one or more of kiwifruit, apple, pear, orange, carrot, grape, mango, tomato, avocado, berries, bean, pea, lime, lemon, feijoa, onion, beetroot, banana, peach, nectarine, paw, pineapple, melon, watermelon, coconut, soybean or by-products and/or derivatives thereof such as pomaces, skins/peels, seeds or roots.

39. The flour composition of claim 38, wherein the plant material contains less than 10% starch.

40. The flour composition of claim 39, wherein the plant material contains less than 2% starch.

41. The process of any one of claims 28 - 40, wherein the lignocellulosic plant material substrate is in a moist or wet pomace, slurry, pulp or paste form.

42. The process of any one of claims 28 – 40 wherein the lignocellulosic plant material substrate is in a dry or semi-dry form, such as a mulch, powder, or coarsely chopped plant material.

43. The process of claim 28, wherein the step of hydrating, drying or maintaining the lignocellulosic plant material substrate achieves a substrate with a moisture content of between 75% - 90%.

44. The process of claim 28, wherein the sterilisation step includes one or more of high temperature sterilisation, high pressure sterilisation, low temperature sterilisation, irradiation or chemical sterilisation.

45. The process of claim 28, wherein the edible higher fungi utilised in the inoculation step are white rot fungi or brown rot fungi.

46. The process of claim 45, wherein the white rot fungi is selected from the genuses *Pleurotus*, *Lentinula, Ganoderma, Volvariella*, *Auricularia*, *Armillaria*, *Flammulina*, *Pholiota*, *Tremella* and/or *Hericium*.

47. The process of claim 45, wherein the brown rot fungi is selected from the genuses *Agaricus*, *Laetiporus* and/or *Sparassis*.

48. The process of claim 28, wherein the incubation step includes incubating the inoculated substrate at 18°C – 30°C for a period of 5 – 50 days.

49. The process of claim 48, wherein the process includes incubating the inoculated substrate at 25°C for 30 days.

50. The process of any one of claims 28 - 49, wherein the flour composition produced by the process comprises between 30 – 90% by weight dietary fibre.

51. The food composition of claim 50, wherein the dietary fibre includes beta glucans.

52. The food composition of claim 51, wherein the beta glucans includes 40% - 65%fungal derived 1,3 and 1,6 beta glucans.

53. The process of any one of claims 28 - 52, wherein the flour composition produced by the process has 150 – 300 calories/100g flour.

54. The process of any one of claims 28 – 52, wherein the flour composition produced by the process has less than 200 calories per 100g flour.

55. The process of any one of claims 28 – 54, wherein the flour composition produced by the process has a linoleic acid content of 2% of total fat or greater.

56. The process of claim 55, wherein the flour composition produced by the process has a linoleic acid content of 30-70% of total fat.

57. The process of claim 28, wherein the step of drying the fermented substrate includes drying the substrate at a temperature of 30° – 40°C.

58. The process of claim 28, wherein the step of drying occurs under vacuum conditions.

59. A process for the production of a composition derived from fungal fermentation of plant material, the composition produced by the process having a total available carbohydrate level of less than the total available carbohydrate level of the starting plant material, the process including the steps of;

a) hydrating, drying or maintaining a lignocellulosic plant material substrate to achieve a substrate moisture level between 45% – 95%;
b) sterilising the substrate of a);
c) inoculating the sterile substrate with an active, edible, higher fungus;
d) incubating the inoculated substrate for a period of time to produce a fermented substrate.

60. The process of claim 59, wherein the fungus used for inoculation in step c) is added at an amount of 5-50% w/w of the hydrated lignocellulosic plant material.

61. The process of claim 60, wherein the active fungus is added at an amount of 10-20% w/w.

62. The process of claim 59, wherein the active, edible fungus utilised in the inoculation step are wood-decay or lignocolous fungi.

63. The process of claim 62, wherein the wood-decay or lignocolous fungi are white rot fungi or brown rot fungi.

64. The process of claim 63, wherein the white rot fungi are selected from the genera *Pleurotus, Lentinula, Ganoderma, Volvariella, Auricularia, Armillaria, Flammulina, Pholiota, Tremella* and/or *Hericium*.

65. The process of claim 63, wherein the brown rot fungi are selected from the genera *Agaricus, Laetiporus* and/or *Sparassis*.

66. The process of claim 59 wherein the process includes the further step of drying or partially drying the fermented substrate.

67. The process of claim 66, wherein the fermented substrate is partially dried to form a paste.

68. The process of claim 66, wherein the fermented substrate is dried to form a free-flowing composition.

69. The process of claim 66, wherein the fermented substrate is dried in a solid form or three dimensional shape.

70. A flour composition produced by the process of claim 28.

71. A composition produced by the process of claim 59.

Figure 1/2

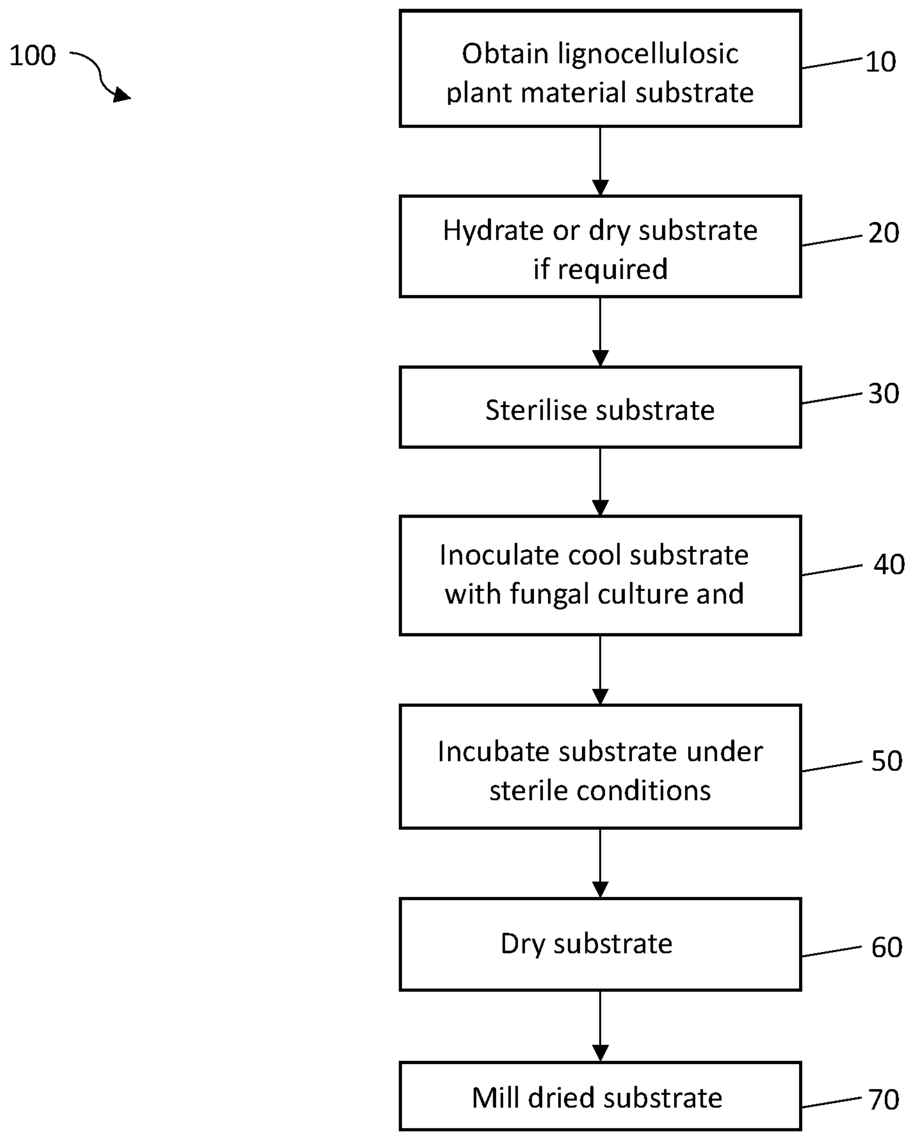
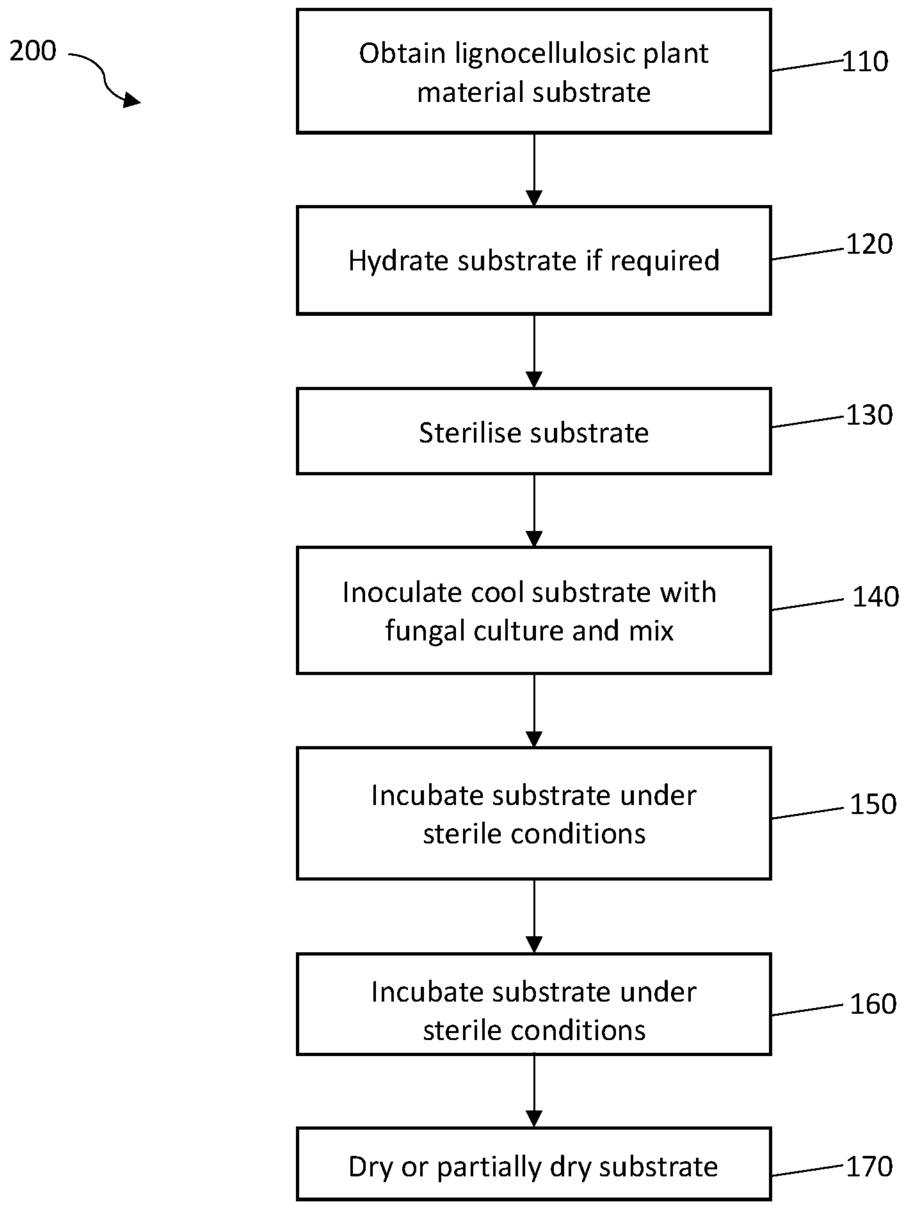

100
Obtain lignocellulosic plant material substrate
10
Hydrate or dry substrate if required
20
Sterilise substrate
30
Inoculate cool substrate with fungal culture and
40
Incubate substrate under sterile conditions
50
Dry substrate
60
Mill dried substrate
70

Figure 2/2


200
Obtain lignocellulosic plant material substrate
110
Hydrate substrate if required
120
Sterilise substrate
130
Inoculate cool substrate with fungal culture and mix
140
Incubate substrate under sterile conditions
150
Incubate substrate under sterile conditions
160
Dry or partially dry substrate
170

INTERNATIONAL SEARCH REPORT	International application No. PCT/NZ2017/050152

A. CLASSIFICATION OF SUBJECT MATTER

A23L 19/00 (2016.01) A23L 7/104 (2016.01) A21D 13/06 (2017.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Patenw, CABA, CAPlus, Biosis, FSTA. A21D13/04, 2/368, 13/06, A23L 11/09, 7/104, 19/00, 33/20, C12R1/645, A23K/low. Keywords: flour, ferment+, carbohydrate, fung+, apple, carrot, orange, kiwifruit and like terms. Google, google patents, scholar-Applicant/inventor names, apple flour, apple powder, fermented flour and like terms. Applicant(s)/Inventor(s) name searched in internal databases provided by IP Australia

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A"	document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
6 February 2018	06 February 2018
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Jake Matic AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262832213

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JOSHI ET AL: "Preparation and evaluation of an animal feed byproduct produced by solid-state fermentation of apple pomace". Bioresource Technology, 1996, vol. 56, pages 251-255 page 252, table 1	1-71
X	ORTIZ-TOVAR et al: "Effect of solid substrate fermentation on the nutritional quality of agro-industrial residues". Interciencia, 2007, vol. 32, pages 339-343. abstract, page 349, table 1	1-71
X	JOSHI ET AL: "Ethanol recovery from solid state fermented apple pomace and evaluation of physio-chemical characteristics of the residue". Natural Product Radiance, 2008, vol. 7, pages 127-132. abstract, table 2, page 128	1-71
X	VILLAS-BOAS et al: "Bioconversion of apple pomace into a nutritionally enriched substrate by Candida utilis and Pleurotus ostreatus". World Journal of Microbiology and Biotechnology, 2003, vol. 19, pages 461-467 abstract, pages 462-463, table 1	1-71
X	ZHANG et al: "Solid-state fermentation of cornmeal with the ascomycete Morchella esculenta for degrading starch and upgrading nutritional value". World Journal of Microbiology and Biotechnology, 2010, vol. 26, pages 15-20. abstract, page 16, table 6	1, 13 and 70
X	QUINN ET AL: "Fungal fermentation of peanut flour: effects on chemical composition and nutritive value". Journal of Food Science, 1975, vol. 40, pages 470-474 page 470, table 1, table 3	1-2, 11-13, 28, 33-34, 36, 41-44, 55-56 and 70
X	ACUN et al: "Effects of grape pomace and grape seed flours on cookie quality". Quality Assurance and Safety of Crops and Foods, 2014, vol. 6, pages 81-88. page 82, table 2	1-4, 13-17, 19-24, 27 and 70-71
X	WO 2012/078256 A1 (KANSAS STATE UNIVERSITY RESEARCH FOUNDATION) 14 June 2012 examples 2, 4-5, tables 2, 8, page 29	1, 11-13, 18, 28, 31-33, 36, 41-44, 55-56 and 70

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:
   the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box

Continuation of: Box III

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-18, 28-58, 70 are directed to flour compositions derived from fungal fermentation of plant material having a metabolizable carbohydrate level between 0.1-50% and methods of producing said flours. The feature of a flour with a metabolizable carbohydrate level between 0.1-50% is specific to this group of claims.

- Claims 19-27, 59-69 and 71 and are directed to a food composition derived from fungal fermentation of a low starch plant material having less than 20% starch, wherein the food composition has a total metabolizable carbohydrate level less than the total metabolizable carbohydrate level of the plant material prior to fermentation. The feature of a food composition derived from fungal fermentation of a low starch plant material having less than 20% w/w starch is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is a food derived from fungal fermentation

However this feature does not make a contribution over the prior art because it is disclosed in:

D1

Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a posteriori.*

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/NZ2017/050152**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
WO 2012/078256 A1	14 June 2012	WO 2012078256 A1	14 Jun 2012
		US 2013224333 A1	29 Aug 2013

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.