

INSTALLATION FOR PRODUCING BEER OR OTHER BEVERAGES AND A PROTEIN-CONTAINING PRODUCT

Installation for producing beer or another beverage and a protein-containing product

The invention relates to a plant for producing beer or another beverage and a protein-containing product based on cereal as input material.

When brewing beer, malt is first produced from barley or other cereal. Malting releases enzymes that produce malt sugar from the starch of the grain for later fermentation. This requires the mashing process. During mashing, the malted and crushed cereal is mixed with brewing water while stirring and heated, the starch is converted into malt sugar (maltose) by the enzymes, and the malt constituents are obtained as an extract. The liquid beer wort is separated from the solid components of the mash, the so-called brewer's spent grain, by lautering in the lauter tun or mash filter at temperatures of 72 to 80 °C. The main product for beer production is the beer wort. This is boiled and hops are added so that its flavor compounds dissolve. Boiling also ensures that the beer wort becomes sterile. After clarification of the beer wort, the fermentation process is initiated by cooling and adding yeast. During fermentation, malt sugar is converted into alcohol and carbon dioxide.

The further treatment of the spent grain, which accumulates in large quantities during beer production, represents a problem, especially for small and medium-sized breweries. The brewer's spent grain removed from the lauter tun has a short microbiological shelf life of only a few days. The brewer's spent grain is used as animal feed in dairy farming and cattle fattening, as fertilizer, for the generation of electricity and heat by means of biogas plants, and in a dried state for heat generation by combustion in combination with wood chips.

The production of proteins for human nutrition using fungi is already known. For example, yeasts have been used for protein production. Under the trade name Quorn™, a meat substitute product produced from the fermented mycelium of the mold (ascomycetes) *Fusarium venenatum* is marketed. In Indonesia, the traditional fermentation product "Tempeh" is produced by inoculating boiled soybeans with various *Rhizopus* species. The fungi are molds from the division of zygomycetes. The fermented mass is cut into pieces, fried, and consumed.

Through fermentation, the proteins of the soybeans are upgraded and digestion-harming components are broken down.

For some years now, there have been efforts to use classic edible fungi from the class of basidiomycetes for the production of proteins and/or flavorings, since these have a high protein content, develop diverse flavors, and the fungal protein has a high biological value.

In a technical article, the production of proteins by fermentation of side streams from the food industry using basidiomycetes is described (Zorn, H. et al. Upcycling of Food Industry Side Streams by Basidiomycetes for Production of a Vegan Protein Source, International Journal of Recycling of Organic Waste in Agriculture 2019, 8:447 - 445). The nutritional value of apple pomace was greatly increased by fermentation with the fungus *Pleurotus sapidus*, and the resulting biomass was considered a suitable alternative protein source. The amino acid content was increased from approximately 5% in the apple pomace to 24% in the fermented apple pomace, and the fermented apple pomace exhibited a high biological value of 86, thereby indicating a good nutritional value for humans.

In a further technical article (Zorn, H. et al. Characterization of the Nutritional Composition of a Biotechnologically Produced Oyster Mushroom and its Physiological Effects in Obese Zucker Rats, Mol. Nutr. Food Res. 2020, 64), physiological (antisteatotic and anti-inflammatory) effects of a nutritional composition of a biotechnologically produced oyster mushroom in studies on a rat model are described.

In a further technical article (Aggelopoulos T. et al: Upgrading of Mixed Food Industry Side-Streams by Solid State Fermentation with *P. ostreatus*", Recycling, Vol. 3, No. 2, April 1, 2018, page 12), the production of a protein-containing fungal mycelium with the help of the basidiomycete *Pleurotus ostreatus* by fermenting a substrate mixture of agro-industrial side streams and wastes is described, which include brewer's spent grain, malt husks, cheese whey, molasses, orange, and tomato paste. The use of a mixture aims to avoid the disposal of the various agro-industrial side streams and wastes and to utilize their different effects on the fermentation in order to produce proteins cost-effectively and to upgrade and minimize wastes. The components of the substrate mixtures are obtained from various sources: cheese whey from an agricultural cooperative, molasses from an alcohol distillery, brewer's spent grain and malt

husks from a beer brewery, tomatoes and oranges from the local market. In the laboratory, 25 different compositions are mixed, the substrate mixtures are sterilized at 120°C for 15 minutes, and the various substrate mixtures are fermented emersely using *P. ostreatus*. A disadvantage is the complex compilation of the substrate mixtures and sterilization prior to fermentation.

According to a further technical article (Ahlborn, J. et al. "Upcycling of food industry side streams by basidiomycetes for production of a vegan protein source", International Journal of Recycling of Organic Waste in Agriculture", Vol. 8, No. S1, December 1, 2019, pages 447-455), apple pomace is fermented using *Pleurotus sapidus* and a protein-rich mycelium is produced. The fermentation is carried out in the laboratory in shake flasks.

In WO 2013/034613 A2, a method for producing a beverage or a beverage base is described, in which, in at least one fermentation process, a medium is fermented that is pumpable, and in which the fermentation process is carried out aerobically, wherein the medium is fermented by mycelium of at least one basidiomycete. In one embodiment, unhopped beer wort is fermented with the mycelium of the basidiomycetes *Ischnoderma benzoinum*, *Tyromyces chioneus*, and *Wolfiporia cocos*. The mycelium of the basidiomycete is separated by centrifugation and the remaining sample is sensorially evaluated. It is found that after aerobic fermentation of unhopped beer wort, appealing-smelling and good-tasting beverages are obtained which differ significantly from unfermented beer wort. This use of the beer wort for beverage production competes with its use for beer production.

EP 3 655 520 B1 describes the production of a protein product from basidiomycete submerged fermentation from a substrate, such as brewer's spent grain.

EP 0 087 139 B1 describes a complete brewing plant in the form of containers.

The international patent application PCT/EP2023/059727, which falls under Art. 54(3) EPC, is based on the object of combining the production of beer or another beverage based on cereal with the production of other products with high nutritional value and thereby making better use of the starting materials and overall achieving an improved ecological balance. For this purpose, mash from malted and/or unmalted cereal is produced as an input material and the mash is fractionated into a first material fraction with a low solids content and into a second material fraction with a high solids content. The first material fraction is used for the production of beer

or another beverage and the second material fraction is inoculated with a fungal inoculum of basidiomycetes. The inoculated material fraction is fermented and a protein-containing fungal mycelium is formed. According to one embodiment, downstream of the mash tun in a lauter tun or lautering device, beer wort and spent grain are separated from each other and the process bifurcates into two strands. In one strand, beer is produced by means of the beer wort. In the other strand, fungal mycelium is produced by means of the spent grain.

The present invention is based on the object of combining the production of beer or another beverage based on cereal with the production of other products with high nutritional value and thereby making better use of the starting materials and overall achieving an improved ecological balance. The combined production of the beverage and other products with high nutritional value is to be executable quickly and flexibly and with the least possible intervention in an existing beverage production.

The object is achieved by a plant for producing beer or another beverage and a protein-containing product according to claim 1.

Advantageous embodiments of the plant are specified in the subclaims and in the description.

The plant according to the invention for producing beer or another beverage and a protein-containing product based on cereal has the following components:

- a brewing plant, comprising a device for producing a mash from malted and/or unmalted cereal, a device for fractionating the mash into a first material fraction with low solids content and into a second material fraction with high solids content, a device for producing beer or another beverage from the first material fraction and an outlet for the second material fraction,
- a fermentation plant for producing a protein-containing product based on cereal, comprising an inlet for the second material fraction, a device for inoculating the second material fraction with a fungal inoculum of basidiomycetes and/or with an inoculum of other microorganisms and a device for fermenting the inoculated material fraction in a submerged culture,

- a device for transporting the second material fraction from the outlet of the brewing plant to the inlet of the fermentation plant,
- wherein the fermentation plant is accommodated at least partially in one or more prefabricated three-dimensional spatial units and
- the brewing plant is a stationary brewing plant.

According to the invention, a material fraction with a high solids content from the mash of a brewing process or another method for producing beverages based on cereal is used for the production of a protein- and/or flavor-containing product with the help of fungi from the class of basidiomycetes.

In the conventional methods for producing beer or other beverages (e.g., whisky) via a mash from malted and/or unmalted cereal, the cereal is only partially processed into substances utilizable by humans. Thus, the yeasts used in beer brewing only partially convert the malted cereal or the beer wort obtained therefrom into substances digestible by humans. The invention makes use of the fact that the components not utilizable by the yeasts during beer brewing, such as cellulose and hemicellulose, can be converted into proteins digestible by humans with the help of basidiomycetes. An advantage here is that the input materials fed to the process are of a quality suitable for the production of beer or other beverages, so that they are fundamentally also suitable for the production of food and other products to be consumed by humans.

In the process, the mash is fractionated into a first material fraction with a low solids content (e.g., beer wort) and into a second material fraction with a high solids content (e.g., brewer's spent grain), the first material fraction is used for the production of beer or other beverages and the second material fraction is used for the production of protein-rich fungal mycelium. The protein-rich fungal mycelium contains various proteins as components of the cells.

In conventional beer production, the material fraction with a high solids content accumulating during the lautering of the beer wort is temporarily stored as brewer's spent grain in large silos and primarily given to the agricultural industry for use as animal feed. However, due to its production using input materials suitable for food production, its material composition, its large quantity share, and its uniform composition and fundamentally high quality, the material

fraction with a high solids content is particularly suitable for the production of proteins for human consumption.

Basidiomycetes (club fungi) include the edible club fungi suitable for human consumption. They possess a very broad biochemical transformation potential and thereby differ from lower fungi and bacteria. According to the invention, this potential is used to provide proteins with a high biological value. Basidiomycetes are capable of forming protein-rich fungal mycelia, the proteins of which can have a high biological value. Studies have shown that spent grain fermented by means of basidiomycetes has a particularly high biological value of over 90 and can therefore be particularly well utilized by humans. The biological value of the fungal proteins is comparable to that of beef and much higher than that of plant proteins or fermented apple pomace. The biological value is a measure for assessing protein quality and indicates how many grams of body protein can be built up by 100 g of the respective dietary protein.

A further advantage of the invention is that it has a high bioconversion rate of at least 10% up to 90%. The bioconversion rate indicates the proportion of the nutrient medium used as a culture substrate that is metabolized into the protein-rich fungal mycelium with the help of the fungus from the class of basidiomycetes. According to the invention, the overall yield with respect to the malted and/or unmalted cereal is greatly improved compared to conventional methods.

In addition, the fermentation products of basidiomycetes can contain flavorings with diverse taste and/or odor aromas, for example flavorings e.g. with fruit, berry, herb, spice, meaty, and/or fishy flavor notes. Studies within the scope of the invention have shown that particularly appealing flavorings are produced during the fermentation of spent grains by means of basidiomycetes. Furthermore, the product obtained by fermentation can contain vitamins important for human nutrition which do not occur in cereal.

Flavorings are volatile compounds in foods that can be perceived with the olfactory receptors. The flavorings reach the receptors either directly through the nose (smelling, nasal perception) or via the pharynx when eating or drinking (retronasal perception) to the receptors. Together with, by definition, non-volatile taste substances (sour, sweet, bitter, salty, or umami-tasting compounds), the flavorings are decisively involved in the aroma of a food. The texture also contributes to the overall sensory impression ("*Flavour*") parameter. As a result of modern

methods for isolating and identifying volatile compounds in foods, over 7,000 flavorings have now been described in the literature (cf. Hartmann-Schreier J., Aromastoffe, RD-01-03286 [2003] in Böckler F., Dill B., Eisenbrand G., Faupel F., Fugmann B., Gamse T., Matissek R., Pohnert G., Rühling A., Schmidt S., Sprenger G., Römpp (Online), Stuttgart, Georg Thieme-Verlag, [March 2023]).

According to the invention, valuable raw materials for the production of beer or other beverages based on cereal are additionally used for the production of nutritionally, gustatorily, and olfactorily particularly effective and interesting products.

In addition to the aforementioned advantageous effects, protein- and/or flavor-containing fungal mycelia produced by means of basidiomycetes can have anti-inflammatory or other health-promoting effects. The fungal mycelium can be used as an end product or raw material for further processing and can be utilized as a vegan meat alternative.

The CO₂ footprint of protein production is much smaller than that of meat production. The ecological balance of the overall process is better than the overall balance of the conventional production of beer or other beverages based on cereal and the production of conventional products that are substituted by the protein- and/or flavor-containing products.

According to the invention, a brewing plant, which can be designed conventionally, is combined with a fermentation plant. The brewing plant has an outlet for the second material fraction, which is, for example, the outlet of a lauter tun for spent grain or the outlet of a spent grain silo. The fermentation plant has an inlet for the second material fraction, which is connected, for example, via a pipeline and a pump to the outlet of the brewing plant. The fermentation plant comprises a device for inoculating the second material fraction with a fungal inoculum of basidiomycetes and a device for fermenting the inoculated material fraction in a submerged culture. It is accommodated at least partially in prefabricated three-dimensional spatial units. The prefabricated three-dimensional spatial units can be transported easily and cost-effectively by rail, road, or water to the place of use. In principle, only a footprint is required for the prefabricated three-dimensional spatial units, for which existing areas can be used. The fermentation plant can be erected without intervention in the brewing plant and without modifying the brewing plant. The prefabricated three-dimensional spatial units can be

assembled in a modular manner here. The structural effort can be kept extremely small overall. The fermentation plant can be set up and put into operation quickly.

The at least partial accommodation of the fermentation plant in prefabricated three-dimensional spatial units allows for a high degree of flexibility with regard to adapting the fermentation plant to the respective brewing plant and to the respective demand for the protein-containing product. In the event of an increased protein demand, rapid and simple expansion is possible due to the modular construction with prefabricated three-dimensional spatial units.

The brewing plant can continue to be operated independently of the fermentation plant without impairment. The second material fraction accumulates anyway during the operation of the brewing plant and is supplied to a higher-value use than previously through processing into protein-rich fungal mycelium. The fermentation plant can in principle be operated independently of the brewing plant. It is possible to use unneeded quantities of the second material fraction in a conventional manner.

Each prefabricated three-dimensional spatial unit is an interchangeable module, and the fermentation plant is composed completely or partially of interchangeable modules in the form of prefabricated three-dimensional spatial units. Differently designed modules are assigned different functions within the fermentation plant. This makes it possible to set up the fermentation plant quickly, adapt it to the respective substrates, working conditions, and desired output quantities, and to rectify defects quickly by exchanging prefabricated three-dimensional spatial units. Furthermore, the prefabricated three-dimensional spatial units can be easily dismantled again and - if necessary after refurbishing - set up again at another location or disassembled and disposed of.

The prefabricated three-dimensional spatial units are designed such that they can be transported by truck on the road to the location of the plant. The height, width, and length of the spatial units are dimensioned such that they are suitable for road transport on trucks. For this purpose, a maximum external width of 6.1 m and a maximum external height of 4.2 m must be adhered to. As a rule, the maximum external length is 20 m.

According to a further embodiment, the dimensions of the prefabricated three-dimensional spatial units adhere to one or more of the following upper limits: a maximum external width of 6.1 m, a maximum external height of 4.2 m, a maximum external length of 20 m.

According to a further embodiment, the dimensions of the prefabricated three-dimensional spatial units fall within one or more of the following ranges: an external width of 1 m to 6.1 m, an external height of 2 m to 4.2 m, an external length of 2 m to 20 m.

The fermentation can optionally also be carried out with the help of other microorganisms, which are used instead of the fungi from the class of basidiomycetes or in addition to them. The microorganisms can be, for example, lactic acid bacteria (Lactobacillales), which can degrade carbohydrates (e.g. present in cereal/malted cereal/in brewer's spent grains) into lactic acid in a lactic acid fermentation. This lactic acid can find various applications in food or also in the technical field, for example as a starting basis for a polymerization process in which PLA is produced by means of lactic acid, which in turn is the starting basis for "bioplastics" that find their application in sustainable packaging.

According to one embodiment of the invention, at least one prefabricated three-dimensional spatial unit is a prefabricated three-dimensional spatial module. The spatial module is designed like a three-dimensional spatial unit in the construction method known in the prior art as "modular construction" or "cellular construction".

According to one embodiment, the prefabricated three-dimensional spatial unit has a building structure made of steel and/or wood and/or concrete. The prefabricated three-dimensional spatial units are spatial units (also referred to as "spatial cells") which are prefabricated in a stationary manufacturing facility, transported to the site of the plant, and erected at the site of the plant. The prefabrication can relate solely to the floors, walls, and ceilings of the spatial units and essential structural elements of the prefabricated three-dimensional spatial units. The still missing components, including the components of the plant to be accommodated in the spatial units, can be installed into the spatial units at the site of the plant. However, the prefabrication can also comprise further components of the spatial units and/or the plant, up to all components which in the finished plant are apportioned to the respective spatial unit. These include in particular the components of the outer shell, in particular facades, ceilings, floors,

insulations, fire protection devices, interior fittings, installations, windows, doors, fittings, etc. Furthermore, during prefabrication, more or less all components of the plant intended for the respective spatial unit can be installed into the spatial units. The components of the spatial units or of the plant can, however, also be installed completely or partially into the spatial units at the site of the plant.

According to another embodiment, at least one prefabricated three-dimensional spatial unit is a container. According to a preferred embodiment, the container is a standardized container (ISO container). Containers for the transport of goods by sea, by rail, and by road are available cost-effectively. Further details on standardized containers are given below.

According to one embodiment, the prefabricated three-dimensional spatial unit has at least one defined interface for connecting to another part of the fermentation plant. This promotes setting up the fermentation plant quickly and without errors, expanding it, and rectifying defects by exchanging prefabricated three-dimensional spatial units.

According to one embodiment, the defined interface for connecting to another part of the fermentation plant is an interface for media, electrical power, and/or communication. According to one embodiment, it is an interface which is designed to establish a plug connection, screw connection, snap connection, or clamp connection with an interface of another prefabricated three-dimensional spatial unit or with a line for connecting to a further prefabricated three-dimensional spatial unit.

According to one embodiment, the fermentation plant comprises one or more prefabricated three-dimensional spatial units of the same type, wherein the number of prefabricated three-dimensional spatial units is selected to adapt the throughput of the fermentation plant to the output quantity of the second material fraction available from the brewing plant and/or to adapt the output quantity of the fermentation plant to a predetermined output quantity of the protein-containing product. By using an appropriate number of the prefabricated three-dimensional spatial units, a simple scaling of the fermentation plant is possible in order to adapt it to the available output quantity of the second material fraction and/or to the predetermined output quantity of the protein-containing product.

According to a further embodiment, the plant for producing a protein-containing product comprises at least one of the following prefabricated three-dimensional spatial units:

- prefabricated three-dimensional spatial unit for preparing the second material fraction for fermentation (preparation unit),
- prefabricated three-dimensional spatial unit for producing an inoculum for inoculating a main fermentation (pre-fermentation unit),
- prefabricated three-dimensional spatial unit for carrying out the main fermentation by means of the inoculum and the second material fraction (main fermentation unit),
- prefabricated three-dimensional spatial unit for the dewatering and/or other treatment of the moist fungal mycelium from the main fermentation (product processing unit),
- prefabricated three-dimensional spatial unit for storing the end product (product storage unit),
- prefabricated three-dimensional spatial unit for processing liquid from the final treatment of the moist fungal mycelium (liquid processing unit),
- prefabricated three-dimensional spatial unit for the processing of wastewater (wastewater processing unit),
- prefabricated three-dimensional spatial unit for water, compressed air, steam, and/or other auxiliary media for the production process (auxiliary media unit),
- prefabricated three-dimensional spatial unit for the processing of water, compressed air, steam, and/or other auxiliary media for the production of the protein-containing product (auxiliary media processing unit),
- prefabricated three-dimensional spatial unit for the generation and/or storage of electricity (energy unit),
- prefabricated three-dimensional spatial unit with one for the provision of heat and/or cold (temperature control unit),

- prefabricated three-dimensional spatial unit for a CIP cleaning (cleaning unit),
- prefabricated three-dimensional spatial unit for a distribution of media and/or energy and/or communication signals (distribution unit),
- prefabricated three-dimensional spatial unit for temporarily storing the second material fraction (buffer unit),
- prefabricated three-dimensional spatial unit for the control of the fermentation plant and/or for communication with an external control center spatially separated from the fermentation plant (control unit),
- prefabricated three-dimensional spatial unit for the measurement and checking of properties of the starting products, intermediate products, and/or end products of the fermentation plant (laboratory unit).

In the following, the second material fraction from the brewing plant before and during processing in the fermentation plant is simply referred to as "spent grain". The respective explanations apply accordingly to other second material fractions and to other brewery side streams that are processed in addition to the further material fraction.

The preparation unit is intended for preparing the spent grain for fermentation. The preparation unit serves to provide an inlet for the spent grain, to mix the spent grain with liquids, to comminute it for the fermentation, and/or to treat it thermally. According to one embodiment, the preparation unit has an inlet for spent grain and for water and liquids from the brewing process, a device for comminuting spent grain, and/or a buffer vessel for the comminuted spent grain, and/or a device for thermal treatment, and/or another device for microbiologically stabilizing and/or for technically sterilizing spent grain. According to a further embodiment, the device for thermal treatment is a heating device which heats the spent grain in the preparation unit in such a way that a sterilization of the spent grain or of the spent grain-liquid mixture takes place. Further devices for microbiologically stabilizing and/or technically sterilizing are described in the following description. According to one embodiment, one or more of these devices for microbiological stabilization are arranged in the preparation unit. The device for comminuting spent grain creates a larger attack surface for the basidiomycetes and

increases the speed of the bioconversion of the input material fraction to fungal mycelium containing proteins and/or flavorings.

The spent grain prepared for fermentation is transported from the preparation unit into the pre-fermentation unit.

The pre-fermentation unit serves to produce an inoculum which is used to inoculate the second material fraction in the main fermenter. The pre-fermentation unit comprises one, two, or more small fermenters in which the inoculum is produced. According to one embodiment, the small fermenter comprises an agitator. The agitator serves to homogenize the inoculum. This promotes uniform and reproducible conditions for the fermentation, so that optimal conditions can be maintained and the speed of the bioconversion can be increased.

The main fermentation unit comprises one or more main fermenters in which the main fermentation is carried out. For this purpose, the prepared spent grain from the preparation unit is inoculated in the main fermenter by means of the inoculum from the pre-fermentation unit, and the main fermentation is carried out. Via lines, the prepared spent grain can be transported from the preparation unit partly to the pre-fermentation unit for producing the inoculum and partly to the main fermentation unit for carrying out the main fermentation. According to one embodiment, the main fermenter comprises an agitator. The prepared spent grain, the inoculum, and optionally additionally supplied water are homogenized by the agitator. This promotes uniform and reproducible conditions for the fermentation, so that optimal conditions can be maintained and the speed of the bioconversion can be increased.

According to one embodiment, the main fermentation unit comprises a device for adding water into the main fermenter. By adding water, the material fraction used for the production of proteins is diluted and cooled. For this purpose, the water preferably has a temperature below 30 °C. The addition of water simultaneously allows an optimal water content of the material fraction and an optimal temperature for the fermentation to be set.

According to one embodiment, the inoculum is fed into the main fermenter separately from the material fraction to be fermented and is mixed with the material fraction to be fermented in the main fermenter.

According to one embodiment, the material fraction to be fermented is mixed with the inoculum before being fed into the main fermenter. The mixing with the inoculum can take place before, during, or after mixing the material fraction to be fermented with water.

The inoculated material fraction is fermented in a submerged culture. Here, the fermentation is carried out within the dispersion of the input material fraction and the inoculum in the aqueous phase. Submerged fermentation is advantageous because it is possible to work with liquid or pumpable media in mixing, reaction, and storage vessels and in pipelines and pumps and/or other conveying devices connecting them.

According to one embodiment, the pre-fermentation unit and/or the main fermentation unit is designed as a standardized tank container or on the basis of a standardized tank container. A pre-fermentation unit and/or main fermentation unit designed on the basis of a standardized tank container can in particular be provided with an agitator and/or with a device for temperature control of the medium in the tank of the tank container to a desired temperature, which is advantageous for carrying out the fermentation. The device for temperature control can be a device for cooling and/or for heating the medium in the tank. According to one embodiment, the tank container is set up vertically, so that its main direction of extension is aligned vertically. As a result, the smallest possible area of the tank container stands on the ground. This achieves a space-saving arrangement of the tank container.

According to another embodiment, one or more devices for fermenting have at least one freestanding fermenter. The freestanding fermenter is not arranged in a prefabricated three-dimensional spatial unit and stands freely on the grounds of the plant. This can be a fermenter for the pre-fermentation or a main fermenter for the main fermentation.

The product processing unit serves for the dewatering and/or other treatment of the moist fungal mycelium from the main fermentation. For this purpose, the product processing unit is provided with a device for dewatering and/or with another device for *downstream processing*. Via a line, the fungal mycelium can be transported from the main fermentation in the main fermentation unit for *downstream processing* in the product processing unit.

The product storage unit serves for storing the end product. According to one embodiment, this is a simple standard container. According to a further embodiment, the product storage unit is

a standard container with a device for temperature control of the products stored therein. According to a further embodiment, the product storage container is a refrigerated container or a freezer container. Via a line and/or transport device, the processed product can be transferred from the product processing unit into a product storage unit. In a product storage unit (in particular in a product storage container), the product can be transported by truck, train, or ship to the site of further processing.

The liquid processing unit serves to process the liquid from the product treatment in the product processing unit. According to one embodiment, devices for filtering, for centrifuging, for membrane separation, for extracting, for absorbing, for adsorbing, or other mechanical, thermal, biological, chemical, and/or physical separation devices are used for this purpose. The liquid processing unit is connected to the product processing unit via a further line.

The wastewater processing unit serves to process wastewater from the liquid processing unit. According to one embodiment, it has a mechanical, thermal, biological, chemical, and/or physical device for wastewater processing. The processing of the liquid from the product processing unit and the processing of the wastewater can also be combined in a single prefabricated three-dimensional spatial unit (liquid processing and wastewater unit).

The auxiliary media unit serves to provide water, steam, compressed air, and/or other media for the production process. According to one embodiment, it contains at least one device for providing one of these media. The water is needed to set the liquid content of the substrate for the submerged fermentation. Hot steam is needed in particular for cleaning and sterilizing components and lines of the plant. Compressed air is needed in particular for the operation of valves as well as the aeration of the fermenters. The media unit is connected via lines to one or more further prefabricated three-dimensional spatial units of the plant.

The auxiliary media processing unit serves to sterilize the media water, steam, and compressed air in order to use them for the fermentation. According to one embodiment, the prefabricated three-dimensional spatial unit contains for this purpose a sterile water filtration system and/or a device for steam filtration and/or a device for compressed air filtration.

The energy unit serves to generate and/or store electricity for the various electrical consumers of the fermentation plant and to provide it for the individual consumers. According to one

embodiment, the energy unit contains a power generator, an accumulator, a battery, and/or a fuel cell. The energy unit can be designed to permanently supply the fermentation plant with electricity. However, it can also be designed to ensure a temporary supply of electricity to the fermentation plant in the event of power failures.

The temperature control unit serves to provide heat and/or cold for temperature control of one or more components of the fermentation plant. In particular, the temperature control unit serves to provide heat and/or cold for temperature control of a pre-fermenter and/or a main fermenter. According to a further embodiment, the temperature control unit contains a heating system and/or a cooling system. According to a further embodiment, the temperature control unit contains a heat pump, wherein parts of the fermentation plant can simultaneously be cooled and other parts can be heated by means of the heat pump. The temperature control unit can be connected to one or more further prefabricated three-dimensional spatial units via lines that are filled with heat transfer liquid.

The cleaning unit serves to provide media for a CIP cleaning for cleaning plant components and lines. The media can be acid, lye, and/or water. According to one embodiment, the media are stored in canisters or other vessels in the cleaning unit. According to one embodiment, the cleaning unit comprises a device for mixing different media for the CIP cleaning. According to one embodiment, the cleaning unit comprises a pump or another conveying device for transporting the material composition for the CIP cleaning to the cleaning location. The cleaning unit is connected to one or more components or lines of the fermentation plant via one or more lines. The term "*cleaning in place*" (CIP) denotes a method for cleaning process engineering plants (in particular, e.g., biotechnical or food technology plants). In this cleaning method, the plant is cleaned on the surfaces that come into contact with the product without essential dismantling. A reproducible process is defined by exactly specifying cleaning agents, pressures, temperatures, and exposure times.

The distribution unit serves to distribute media and/or energy and/or communication signals of different components of the plant. According to one embodiment, the distribution unit has various interfaces for the connection of lines for (liquid) media, for energy (e.g., power cables), and/or for data (e.g., data cables or optical fibers). These can be interfaces for feeding in media and/or energy and/or data and interfaces for outputting media and/or energy and/or data. The

interfaces for feeding in and for outputting are connected to each other in a defined manner within the prefabricated three-dimensional spatial unit.

The buffer unit serves to temporarily store the spent grain from the brewing plant before it is further processed in the fermentation plant. According to one embodiment, the buffer unit is a tank container. According to one embodiment, the buffer unit has a device for temperature control of the spent grain in the buffer unit. According to one embodiment, the buffer unit has means for sterilizing the spent grain. The means for sterilizing the spent grain can be, for example, heating devices (e.g., for ultra-high temperature heating or vapor pressure sterilization) which bring the spent grain in the buffer unit to a temperature at which germs in the spent grain do not accumulate or are rendered harmless. According to one embodiment, the buffer unit is a tank container which is equipped with a heating device and/or a device for stirring. According to one embodiment, the preparation unit is simultaneously a buffer unit.

The control unit serves to control the fermentation plant and/or to communicate with an external control center spatially separated from the fermentation plant. According to one embodiment, the control container contains an electronic data processing system which is designed to control the fermentation plant and/or to communicate with an external control center spatially separated from the fermentation plant. According to one embodiment, the control container comprises at least one interface for the data and/or at least one interface for the power supply. According to one embodiment, the electronic data processing system is designed to control an automatic or essentially automatic sequence of processes in the fermentation plant. This enables a quick commissioning and a continuous operation of the fermentation plant without additional effort for the operation of the brewing plant. According to one embodiment, the electronic data processing system is designed to supply data in real time to the external control center about the state of the media and products in the fermentation plant and/or of one or more components of the fermentation plant. According to one embodiment, at least one prefabricated three-dimensional spatial unit has sensors for detecting the state of the media and products in the fermentation plant and/or of components of the fermentation plant.

According to one embodiment, the external control center is designed to access the control of the fermentation plant in order to monitor or change the operation of the fermentation plant and/or the state of the media in the fermentation plant, to remotely control the fermentation

plant, to carry out remote diagnostics, and/or to carry out remote handling of errors. According to one embodiment, the control center is designed to simulate media, products, components, processes, and/or the entire production in the fermentation plant with the help of the data provided by the control unit. As a result, virtual counterparts of the media, products, components, processes, and/or of the entire fermentation plant are created in the external control center, which are also referred to as "digital twins". A digital twin of the fermentation process can simulate the state of the basidiomycetes cultures in particular in real time. This enables a precise prediction of growth rates, yield, and optimal harvesting times. As a result, fermentation parameters can be adjusted in real time to optimize the process and maximize the yield.

According to one embodiment, the sensors are designed to record all physical and biochemical parameters continuously and in real time. The sensors are installed along the production process and in the supply systems and deliver the raw data to the control unit / the electronic data processing system via compatible interfaces. According to one embodiment, these are used for the generation of a virtual counterpart. According to one embodiment, the recorded data are transmitted to an external control center wirelessly, via cable, or via satellite. There they can be fed to a central data platform. According to one embodiment, the data transmission takes place via secure network protocols in order to ensure the integrity and security of the data.

The laboratory unit serves to measure and check the properties of the starting products, in particular the spent grain, the basidiomycetes, and the auxiliary media, of the intermediate products, in particular the prepared spent grain of the inoculum, and of the end products, in particular the fungal mycelium and the wastewater. For the measurement, sensors can be arranged in the various plant components and/or measuring apparatuses can be used in the laboratory unit, in which samples are analyzed. The samples can be fed to the measuring apparatuses via sample lines and/or be taken at the respective plant components and transported to the measuring apparatuses in the laboratory unit. The results of the measurements can be used in particular for the control of the process, quality control, and the verification of specifications to be adhered to.

According to one embodiment, several prefabricated three-dimensional spatial units are arranged next to one another and/or one above the other. This enables a space-saving arrangement of the fermentation plant and a scaling in order to achieve the desired output

quantities. According to one embodiment, several prefabricated three-dimensional spatial units are arranged around one or more media units. This enables a particularly efficient distribution of liquids, energy, and/or data. According to one embodiment, several prefabricated three-dimensional spatial units are arranged in parallel. This enables a particularly space-saving accommodation. According to one embodiment, one or more containers are aligned horizontally and/or one or more containers are aligned vertically. Depending on the function of the container, a horizontal or vertical alignment can be advantageous. According to one embodiment, several prefabricated three-dimensional spatial units are arranged in groups next to each other. This is advantageous for connecting different prefabricated three-dimensional spatial units via interfaces and/or lines. Furthermore, the arrangement of the prefabricated three-dimensional spatial units in groups in which prefabricated three-dimensional spatial units with the same function are put together can facilitate the assembly of the fermentation plant, the monitoring, maintenance, servicing, maintaining certain operating states (e.g., the operating temperature), and increase operational safety.

According to one embodiment, prefabricated three-dimensional spatial units carrying liquid media are arranged on a lower level and/or prefabricated three-dimensional spatial units serving for communication, data processing, control, energy supply, and/or temperature control are arranged on a higher level.

According to one embodiment, at least one container is a standardized 20-foot container and/or at least one container is a standardized 40-foot container and/or at least one container is a standardized 45-foot container. Standardized containers (ISO containers) are standardized large-capacity steel receptacles which are used in particular for the transport of freight by water, by rail, and by road. In relevant standards, in particular dimensions, mountings, and stackability are specified in accordance with ISO standard 668. The most widely used ISO containers have a width of 8 feet (2.4384 m), a height of 8 feet 6 inches (2.591 m), and a length of either 20 feet (6.058 m) or 40 feet (12.192 m). ISO containers can in particular be designed as standard containers, refrigerated containers, or tank containers. Within the scope of the invention, other standardized containers can also be used. Containers suitable for truck transport are preferably used.

The brewing plant is a stationary brewing plant. The invention can be realized in particular by combining existing stationary brewing plants with the fermentation plant. According to a further embodiment, the prefabricated three-dimensional spatial units are arranged at least partially on foundations. The foundations are, for example, concrete slabs, strip foundations, or point foundations.

According to one embodiment, the fermentation plant is placed at least partially on truck spaces for the removal of spent grains or another brewery side stream next to the brewing plant. Breweries generally have truck spaces next to the spent grain silo for the removal of spent grain, which can be used for setting up the fermentation plant.

According to one embodiment, the outlet for the second material fraction of the brewing plant is connected to the inlet for the second material fraction of the fermentation plant via a pipeline and/or a pump and/or a buffer vessel. According to one embodiment, the spent grain is conveyed from the outlet of the brewing plant to the inlet of the fermentation plant by means of compressed air. Via the buffer vessel, fluctuations in the output quantity of the second material fraction can be buffered and/or a sterilization of the second material fraction can be carried out over a sufficient period of time to render the second material fraction germ-free for further processing. According to a further embodiment, the buffer vessel is a tank container or a silo for storing spent grain or another brewery side stream. A silo for a brewery side stream that is present in a brewery anyway can be used for this purpose.

According to one embodiment, the brewing process or another method for producing beverages in the brewing plant and the production of proteins in the fermentation plant are carried out inline. Here, the brewing plant and the fermentation plant are continuously connected to one another to form a coherent plant. In terms of plant engineering, this is realized in particular by physically connecting the plant parts for carrying out the brewing process or other method for producing beverages with the plant parts for the production of proteins via lines and/or continuously or intermittently operating conveying systems to form an overall plant.

According to one embodiment, the device for transporting the second material fraction from the outlet of the brewing plant to the inlet of the fermentation plant comprises at least one transport vehicle. According to a further embodiment, the transport vehicle is a truck, a railway

train, and/or a ship. According to this embodiment, the material fraction with a high solids content is transported for fermentation to a more or less distant location by truck, railway train, ship, or another transport vehicle after the liquid beer wort has been lautered off. This can be an internal or external transport. According to a further embodiment, the material fraction with a high solids content is transported by means of a truck with a (semi-) trailer. According to a further embodiment, the material fraction with a high solids content is transported by means of tank trucks. According to a further embodiment, the transport vehicle is filled directly with the material fraction with a high solids content taken from the lauter tun, or this material fraction is temporarily stored in a silo and the transport vehicle is filled with the material fraction after the temporary storage.

According to one embodiment, the material fraction used for the production of proteins is diluted with water. By diluting with water, the material fraction can be made capable of flowing and pumping and brought into a state suitable for a fermentation in a submerged culture. This applies in particular to the preparation of the material fraction with a high solids content from the mash and/or to the preparation of malted and/or unmalted cereal from the malting process for fermentation.

According to one embodiment, the material fraction used for the production of proteins is processed freshly and/or microbiologically stabilized and/or made technically sterile. The material fraction is considered to be freshly processed and/or microbiologically stabilized and/or technically sterile if no pathogenic microorganisms accumulate in the material fraction after separating the material fraction from the mash. The brewer's spent grain accumulating in the lauter tun can be referred to as technically sterile.

According to one embodiment of the invention, the outlet of the brewing plant for the second material fraction is the outlet of the lauter tun or another lautering device for spent grain. According to one embodiment, the spent grain from the lautering device is microbiologically stabilized. Through microbiological stabilization, microorganisms which cannot be completely excluded in view of a maximum temperature of 78°C during mashing cannot accumulate in the further process and contaminate the product. According to one embodiment of the invention, the outlet of the brewing plant for the second material fraction is the outlet of a spent grain silo. As a result of storage in large silos, the spent grain accumulating during conventional beer

brewing is rich in microorganisms, and an accumulation of pathogens cannot be excluded, so that the spent grain generally does not meet the hygienic requirements for processing into a foodstuff. According to one embodiment, the spent grain from the spent grain silo is microbiologically stabilized.

According to one embodiment, the second material fraction used for the production of proteins is freshly processed and/or microbiologically stabilized and/or made technically sterile by at least one of the following measures:

- Through short dwell times from the accumulation to the fermentation of the material fraction (preferably of at most 24 hours, more preferably at most 12 hours, more preferably at most 4 hours),
- by a post-heating to at least 80 °C, preferably to at least 90 °C, preferably by autoclaving,
- by cooling down to a temperature below 30°C,
- by adding acid, preferably lactic acid, preferably lactic acid from the brewing process or other methods for producing foods,
- by using basidiomycetes that form antimicrobial compounds,
- by regularly, preferably at least daily, emptying, cleaning, and sterilizing the plant parts of a production plant for carrying out the method or of a transport vehicle for transporting the material fraction (e.g., silos, lines, screw conveyors, tanks) through which the material fraction is guided and/or in which it is stored.

According to a further embodiment, a post-heating of the material fraction used for the production of proteins to a temperature in the range of 90 °C to 130 °C takes place.

One or more of the aforementioned measures for microbiologically stabilizing and/or technically sterilizing the second material fraction used for the production of proteins are carried out at least to an extent that ensures microbiological stabilization up to the bioconversion of the substrate into protein-rich fungal mycelium. Studies with fungal mycelia have shown that these are microbiologically comparatively stable.

According to one embodiment, the device for transporting the second material fraction from the outlet of the brewing plant to the inlet of the fermentation plant and/or the fermentation plant is designed to carry out one or more of the aforementioned measures for microbiologically stabilizing and/or technically sterilizing the second material fraction. According to one embodiment, the device for transporting and/or the fermentation plant is equipped with a device for post-heating, a device for adding acid, a device for adding basidiomycetes, and/or a device for cleaning and sterilizing. According to one embodiment, the device for microbiologically stabilizing and/or technically sterilizing is arranged in one or more containers of the fermentation plant.

Short dwell times can be achieved in particular by carrying out the brewing process or another method for producing beverages and the production of proteins inline. Due to the direct (inline) processing, the spent grain is poorer in microorganisms than the spent grain that is first stored in a silo, and it contains no pathogenic germs. If the material fraction with a high solids content is transported to the site of fermentation by means of a transport vehicle after removal from the lauter tun, the dwell time can be kept short in particular by filling the material fraction directly into the transport vehicle or filling it into the transport vehicle after a short temporary storage and/or by short timing of the transports by means of the transport vehicle. A microbiological stabilization by post-heating and/or by cooling down the material fraction with a high solids content can take place in particular during a temporary storage in a silo and/or in a tank of a transport vehicle. For this purpose, plant parts of a production plant or of a transport vehicle can be correspondingly heated and/or cooled and/or the material fraction can be temperature-controlled and diluted with heated and/or cooled water. The hygienic requirements for the microbiological stabilization of the material fraction with a high solid content result from the German Food and Feed Code (LFGB) in the version of the announcement of September 15, 2021. The transport of the material fraction by transport vehicles in accordance with the hygiene requirements can be supervised by certified quality assurance.

Embodiments which can be realized by appropriate design of the plant components in the containers, feeding of appropriate starting materials into the fermentation plant, and/or further processing of the product generated in the fermentation plant are indicated below.

According to one embodiment, the fermentation broth is stirred and/or pumped around during the fermentation. By stirring and/or pumping around, the fermentation broth formed from the inoculated material fraction and the aqueous phase is homogenized and the maintenance of optimal conditions for the fermentation is promoted.

According to one embodiment, the fermentation is carried out at a temperature between 18°C and 30°C, preferably between 20°C and 26°C. This temperature range is mostly optimal for fermentation by means of basidiomycetes.

According to one embodiment, the substrate composition during the fermentation is set such that the C content is 4 to 20 g/l, the N content is 0.5 to 5 g/l, and/or the C/N ratio is approx. 10 to 40. By maintaining these parameters, the nutrient requirements of the basidiomycetes are usually covered.

According to one embodiment, the protein-containing fungal mycelium is separated from the fungal mash formed during the fermentation. This dehydrates the product and enriches the proteins and/or flavorings. According to one embodiment, the fungal mycelium is separated from the fungal mash by filtering, decanting, centrifuging, or precipitating.

According to one embodiment, the protein-containing fungal mycelium is used as an end product, for example as food or a nutraceutical, i.e., as food with additional pharmaceutical benefits. According to one embodiment, the proteins and/or flavorings are at least partially separated from the fungal mycelium, preferably by extraction. The separated substances are, for example, used directly as an end product or processed with other substances into end products.

According to one embodiment, residues accumulating during the brewing process and/or during the manufacturing process for fungal mycelium are fed to a preceding process step, optionally after a treatment. The residues can be used in particular as the material fraction to be fermented or as fertilizer in the cultivation of the cereal. The residues can also be used in a biogas plant. The digestate of the biogas plant can be used as fertilizer for the cultivation of cereal.

According to one embodiment, the fungal mycelium is processed into a food, supplement, nutraceutical, luxury food, feedstuff, or medicinal product. According to one embodiment, the

proteins and/or flavorings are extracted from the fungal mycelium and processed into a food, supplement, nutraceutical, luxury food, or medicinal product.

According to one embodiment, the club fungus is selected from the following group of fungi: *Pleurotus eryngii*, *Pholiota nameko*, *Cyclocybe aegerita*. With these basidiomycetes, protein mixtures with a high biological value, attractive flavor profiles, and low gluten content can be achieved. According to one embodiment, the mixture of proteins has a biological value of at least 94, preferably at least 97.

According to one embodiment, the container comprises lines for media and/or energy and/or communication in the upper region and/or one or more interfaces for connecting with further containers in the outer wall and/or units for production, storage vessels, control devices, and/or electronic data processing systems in the lower region.

With the help of selected basidiomycetes, protein-containing products were produced from spent grain. For this purpose, the basidiomycetes listed in Table 1 below were used:

Table 1: Used basidiomycetes.

Strain	Trivial name	Abbreviation	Internal Strain No.	Origin	Strain No.
<i>Pleurotus eryngii</i>	King oyster mushroom	PER	100	DSMZ	8264
<i>Pholiota nameko</i>	Nameko mushroom	PNA	113	DSMZ	6908
<i>Cyclocybe aegerita</i>	Poplar mushroom	AAE	166	Fa. Sylvan, Horst, NL	4022

Details on the execution of the study and its results are described in the international patent application PCT/EP2023/059727. In this respect, reference is made to the international patent application no. PCT/EP2023/059727, the content of which is hereby incorporated into this

application. This applies in particular to page 34, para. 3 to page 53 of the international patent application.

The invention will be explained in more detail below with reference to the accompanying drawings of exemplary embodiments. In the drawings:

- Fig. 1 shows a plant comprising a brewing plant and a fermentation plant for producing a protein-containing product in a simplified process diagram;
- Fig. 2 shows a fermentation plant for producing a protein-containing product with the plant components in various containers in a highly schematic vertical section;
- Fig. 3 shows a fermentation plant for producing a protein-containing product with four main fermenters in a top view;
- Fig. 4 shows a fermentation plant with eight main fermenters in a highly schematic top view;
- Fig. 5 shows the same fermentation plant in a perspective view obliquely from above.

According to Fig. 1, beer brewing and protein extraction begin with the germination of barley or another cereal and its conversion into enzyme-containing malt. In a device for producing a mash 1, the malt is crushed and mixed with warm water. This mash is poured into a mash tun. Here, within a few (1 to 2) hours, malt sugar (maltose), glucose (dextrose), and other sugars are formed from the cereal starch stored in the malt grains by the action of starch-degrading enzymes (amylases). Cell wall-degrading enzymes (cellulases) break down the outer husks of the barley grains so that the amylase can attack the starch inside the grain.

Downstream of the mash tun, in the lauter tun or lautering device (device for fractionating the mash) 2, beer wort and spent grain are separated from one another, and the process bifurcates into two strands. Subsequently, in a device for producing beer 3, the liquid, sweet portion of the mash (beer wort) is introduced into a wort kettle (upper strand). Hops are added here. This gives the beer its spicy-bitter taste. The brewer fills the resulting wort into a fermentation vat or fermentation tank and adds (brewer's) yeast. Then the alcoholic fermentation begins. After fermentation, the beer is stored in tanks for some time to mature and is subsequently bottled in bottles and kegs. In this way, it reaches the customer via retail or gastronomy.

In a fermentation plant 4, the solid components of the mash (material fraction with increased solids content) are filtered off and used as a substrate for the subsequent process of producing a fungal mycelium by fermentation by means of basidiomycetes in a fermenter (lower strand). The inlet 4.1 of the fermentation plant 4 is connected to the outlet 2.2 of the device for fractionating 2 for spent grain via a device for transporting 5 in the form of a pipeline.

Fig. 2 shows a distribution of the various components of a fermentation plant 5 among containers. Each large rectangular box represents a standardized container. Inside the containers, components of the fermentation plant are depicted by means of small rectangular boxes or circles. Lines are each symbolized by a pair of parallel lines. Interfaces in the outer walls of the containers for connecting to containers or lines are symbolized by blackened boxes.

On the lowest level, from left to right, a preparation container 6, a pre-fermentation container 7, a main fermentation container 8, a product processing container 9, a liquid processing container 10, and a wastewater processing container 11 are shown. The said containers are placed on the ground 12, wherein only the main fermentation container 8 is placed vertically with a small end face on the ground, and the other containers lie horizontally on the ground.

The preparation container 6 comprises the inlet of the fermentation plant, which is designed as an interface in a container wall. In the preparation container, a device for comminuting 6.1 the spent grain, a buffer vessel 6.2 for the comminuted spent grain, and a device for the thermal treatment 6.3 of the spent grain and of water for diluting the spent grain are arranged. The device for comminuting 6.1 is connected on the inlet side to the inlet and on the outlet side to the buffer vessel 6.1 for the spent grain via lines. Via further lines, the buffer vessel 6.1 for the spent grain is connected on the outlet side to the device for thermal treatment 6.3, and the latter is connected on the outlet side to an interface for the prepared spent grain in the container wall opposite the container wall with the inlet. An interface for feeding in untreated water is provided in the container wall with the inlet, and a further interface for outputting thermally treated water is provided in the opposite container wall. The first-mentioned interface is connected via a line to an inlet of the device for thermal treatment, and the second-mentioned interface is connected via a line to the outlet of the device for thermal treatment 6.3.

The pre-fermentation container 7 contains a small fermenter 7.1 for a pre-culture and a larger pre-fermenter 7.2 for producing an inoculum. The pre-fermentation container 7 comprises interfaces for feeding in pretreated spent grain and pretreated water in one container wall. In an opposite container wall, it comprises interfaces for outputting pretreated spent grain, inoculum, and pretreated water. The interfaces for feeding in pretreated spent grain and pretreated water are connected via lines to the inlet of the small fermenter 7.1 and of the pre-fermenter 7.2. The small fermenter 7.1 is connected on the outlet side to the line for conducting the pretreated water into the pre-fermenter 7.2. The pre-fermenter 7.2 is connected on the outlet side via a line to the interface for the exit of inoculum. The lines for pretreated spent grain and for pretreated water are connected to the interfaces for the outlet of pretreated spent grain and pretreated water.

The main fermentation container 8 is designed on the basis of a standardized tank container. The tank container has a large tank in a laterally open container frame, which is used as a main fermenter. The tank container is additionally provided with an agitator and a device for temperature control, which are not shown in the figure. The main fermentation container has interfaces for feeding in pretreated spent grain, inoculum, and pretreated water on one side of the container wall. These interfaces on the inlet side are connected to the interfaces on the outlet side of the pre-fermentation container 7. The said interfaces are connected to each other either directly or via lines. On a side opposite the side with the interfaces on the inlet side, the main fermentation container 8 has an interface for the outlet of moist fungal mycelium.

The product processing container 9 has an interface for moist fungal mycelium in one container wall and interfaces for dewatered end product and for liquid from the dewatering in an opposite container wall. A device for dewatering 9.1 and a device for a final *downstream processing* 9.2 are arranged in the product processing container. The device for dewatering 9.1 is connected on the inlet side via a line to the interface for moist fungal mycelium of the main fermentation container 8 and on the outlet side via lines to the device for final *downstream processing* 9.2 and to the interface for the separated liquid. The device for final *downstream processing* 9.2 is connected on the outlet side via a line to the interface for the dewatered fungal mycelium. The interface for the moist fungal mycelium is connected directly or via lines to the interface for the fungal mycelium of the main fermentation container 8.

The liquid processing container 10 has an interface for feeding in the separated liquid in one container wall and an interface for outputting wastewater in the opposite container wall. The liquid processing container comprises a device for processing 10.1 the separated liquid, which comprises a centrifuge, an ultrafiltration, and a collection tank. The device for processing 10.1 the separated liquid is connected on the inlet side via a line to the interface for feeding in the separated liquid and on the outlet side via a line to the interface for the wastewater. The liquid processing container 10 is connected via the interface for feeding in the separated liquid directly or via a pipeline to the interface for outputting separated liquid of the product processing container 9.

The wastewater cleaning container 11 has an interface for feeding in wastewater in one container wall and an interface for outputting pure water in the opposite container wall. A device for biological and/or mechanical wastewater processing 11.1 is arranged in the wastewater processing container. This is connected via lines on the inlet side to the interface for feeding in wastewater and on the outlet side to the interface for outputting pure water.

On the second level, from left to right, the fermentation plant 5 has an auxiliary media container 13, an auxiliary media processing container 14, a distribution container 15, and a cleaning container 16. The containers on the second level are either placed on a support structure 17 above the containers on the lowest level or are placed directly on the containers of the lowest level.

The auxiliary media container 13 has interfaces for the inlet of pure water, air, and tap water in one container wall. In the opposite container wall, it has interfaces for the outlet of water, compressed air, and steam. A water tank 13.1, a compressed air generator 13.2, and a steam generator 13.3 are arranged inside the auxiliary media container, which are connected on the inlet side via lines to the interfaces for the respective medium in the first-mentioned container wall and on the outlet side to the interfaces for the respective medium in the second-mentioned container wall.

The auxiliary media processing container 14 has interfaces for the inlet of water, compressed air, and steam in a first container wall. In an opposite container wall, it has interfaces for processed water, compressed air, and steam. Devices for processing 14.1 water (e.g., pre-

filtration and main filtration devices), a device for compressed air processing 14.2, and a device for steam processing 14.3 are arranged in the auxiliary media processing container 14. These are connected via lines on the inlet side to the interfaces for the corresponding media in the first-mentioned container wall and on the outlet side to the interfaces for the corresponding media in the second-mentioned container wall. The first-mentioned interfaces are connected directly or via lines to the interfaces on the outlet side of the auxiliary media container 13.

The distribution container 15 has interfaces for feeding in processed water, compressed air, and steam in one container wall. In an opposite container wall, it has interfaces for outputting water, compressed air, steam, coolant medium, heat transfer medium, and electrical power. In a further container wall, it has interfaces for feeding in coolant medium, heat transfer medium, and electrical power. Lines and pipe branches of a central media distribution 15.1 are arranged in the distribution container 15, which connect the interfaces on the inlet side to the interfaces on the outlet side. The distribution container is connected via the first-mentioned interfaces directly or via lines to the interfaces on the outlet side of the auxiliary media processing container 14. The interfaces on the outlet side are connected via lines, not shown, to the containers that have a demand for the respective media. For example, the outlets for the coolant and heat transfer media are connected to a temperature control device of the main fermentation container 8 in order to set a desired temperature in the main fermenter.

The cleaning container 16 has an interface for cleaning liquid in one container wall. Canisters and/or tanks containing acid, lye, and water 16.1, 16.2, 16.3 as well as a mixing vessel 16.4 for mixing these liquids to form a cleaning liquid are arranged in the cleaning container. The mixing vessel 16.4 is connected on the outlet side via a line to an interface in the container wall. The interface is connected via lines, not shown, to containers that require cleaning.

On the third level, from left to right, an energy container 18, a temperature control container 19, and a control container 20 are arranged. These containers are placed on a support structure 21 above the containers on the second level or are placed directly on containers on the second level.

The energy container 18 has an interface for electrical power in one container wall. A power generator 18.1, an electricity storage unit 18.2, and a control cabinet 18.3 are arranged in the

energy container. The power generator, electricity storage unit, control cabinet, and interface are connected to one another via cables.

The temperature control container 19 has an interface for feeding in electrical power in one container wall and interfaces for outputting electrical power as well as outputting heat transfer medium and coolant medium in an opposite container wall. A heating system 19.1 and a cooling system 19.2 are arranged in the temperature control container, which are connected via lines to the aforementioned interfaces for coolant medium and heat transfer medium. Furthermore, a control cabinet 19.3 for controlling the heating system and cooling system is arranged in the temperature control container. The temperature control container 19 is connected via its interface on the inlet side, either directly or via cables, to the interface on the outlet side of the energy container. Its interface for electrical power on the outlet side is connected via cables to the corresponding interface of the distribution container 15, and the interfaces for the coolant medium and the heat transfer medium are connected via lines to the interfaces on the inlet side for the corresponding media of the distribution container 15.

The control container 20 comprises an electronic data processing system 20.1 and devices for controlling 20.2 plant components. Furthermore, it has interfaces for electrical power and data. The interfaces are connected via cables, not shown, to the corresponding interfaces of the other containers.

According to Fig. 3, the distribution container 15 is arranged centrally. In front of the distribution container 15, stacked in two rows, the auxiliary media container 13, the auxiliary media processing container 14, the cleaning container 16, and a laboratory container 22 are located at the bottom from left to right, and the control container 20, the energy container 18, and the temperature control container 19 are located at the top from left to right. These containers are aligned with their longitudinal axes perpendicular to the distribution container. Behind the distribution container 15 on the left, two preparation containers 6 and two pre-fermentation containers 7 each are arranged parallel to it, one above the other in two levels. Behind the distribution container, four main fermentation containers 8 with vertical main axes are arranged in two rows next to one another. Behind the distribution container 15 on the right, two product processing containers 9, the liquid processing container 10, and the wastewater processing container 11 are arranged parallel to it, one above the other in two levels.

Furthermore, a part of the pipelines from the distribution container 15 to various other containers are symbolically shown. To the right of the distribution container 15 and the containers in the front row, there is a storage area 23 for storing the end product, in which product storage containers 24, for example standard containers or refrigerated containers, are arranged.

The fermentation plant from Fig. 4 differs from the one described above in that instead of only four main fermentation containers 8, twelve main fermentation containers 8 and a larger number of product processing containers 9, liquid processing containers 10, and wastewater processing containers 11 are provided in order to achieve larger output quantities. The arrangement of the containers in multiple levels is illustrated by Fig. 5. PV panels 25 are additionally arranged on the uppermost containers, which supply the energy container 18 with electrical power. Instead of standardized containers, prefabricated three-dimensional spatial modules can also be used, which can basically be constructed in the same way as prefabricated three-dimensional spatial units which are used in the modular construction of buildings. Furthermore, standardized containers can be used in combination with spatial modules.

LIST OF REFERENCE NUMERALS

- | | |
|----|--------------------------------------|
| 1 | Device for producing a mash |
| 2 | Device for fractionating the mash |
| 3 | Device for producing beer |
| 4 | Fermentation plant |
| 5 | Device for transporting |
| 6 | Preparation container |
| 7 | Pre-fermentation container |
| 8 | Main fermentation container |
| 9 | Product processing container |
| 10 | Liquid processing container |
| 11 | Wastewater processing container |
| 12 | Ground |
| 13 | Auxiliary media container |
| 14 | Auxiliary media processing container |
| 15 | Distribution container |
| 16 | Cleaning container |
| 17 | Support structure |
| 18 | Energy container |
| 19 | Temperature control container |
| 20 | Control container |
| 21 | Support structure |
| 22 | Laboratory container |
| 23 | Storage area |
| 24 | Product storage container |
| 25 | PV panel |

CLAIMS

1. Plant for producing beer or another beverage and a protein-containing product based on cereal with the following components:
 - a brewing plant, comprising a device for producing a mash (1) from malted and/or unmalted cereal, a device for fractionating the mash (2) into a first material fraction with low solids content and into a second material fraction with high solids content, a device for producing beer (3) or another beverage from the first material fraction and an outlet for the second material fraction,
 - a fermentation plant (4) for producing a protein-containing product based on cereal, comprising an inlet for the second material fraction, a device for inoculating the second material fraction with a fungal inoculum of basidiomycetes and/or with an inoculum of other microorganisms and a device for fermenting the inoculated material fraction in a submerged culture,
 - a device for transporting (5) the second material fraction from the outlet (2.1) of the brewing plant to the inlet (4.1) of the fermentation plant,
 - characterized in that
 - the fermentation plant is accommodated at least partially in one or more prefabricated three-dimensional spatial units and
 - the brewing plant is a stationary brewing plant.
2. Plant according to claim 1, wherein at least one prefabricated three-dimensional spatial unit is a prefabricated three-dimensional spatial module.
3. Plant according to claim 1 or 2, wherein at least one prefabricated three-dimensional spatial unit is a container.
4. Plant according to any one of claims 1 to 3, wherein each prefabricated three-dimensional spatial unit has at least one defined interface for connecting to another prefabricated three-dimensional spatial unit of the fermentation plant (4).
5. Plant according to any one of claims 1 to 4, wherein the fermentation plant (4) comprises one or more prefabricated three-dimensional spatial units of the same type, wherein the

number of the prefabricated three-dimensional spatial units is selected to adapt the throughput of the fermentation plant to the output quantity of the second material fraction supplied by the brewing plant and/or to adapt the output quantity of the fermentation plant to a predetermined output quantity of the protein-containing product.

6. Plant for producing according to any one of claims 1 to 5, wherein the plant for producing a protein-containing product comprises at least one of the following prefabricated three-dimensional spatial units:
 - prefabricated three-dimensional spatial unit for preparing the second material fraction for fermentation (preparation unit (6)),
 - prefabricated three-dimensional spatial unit for producing an inoculum for inoculating a main fermentation (pre-fermentation unit (7)),
 - prefabricated three-dimensional spatial unit for carrying out the main fermentation by means of the inoculum and the second material fraction (main fermentation unit (8)),
 - prefabricated three-dimensional spatial unit for the dewatering and/or other final treatment of the moist fungal mycelium from the main fermentation (product processing unit (9)),
 - prefabricated three-dimensional spatial unit for storing the end product (product storage unit (24)),
 - prefabricated three-dimensional spatial unit for processing liquid from the final treatment of the moist fungal mycelium (liquid processing unit (10)),
 - prefabricated three-dimensional spatial unit for water, steam, compressed air and/or other media for the production process (auxiliary media unit (13)),
 - prefabricated three-dimensional spatial unit for the processing of water, compressed air, steam and/or other media for the production of the protein-containing product (auxiliary media processing unit (14)),
 - prefabricated three-dimensional spatial unit for the generation and/or storage of electricity (energy unit (18)),
 - prefabricated three-dimensional spatial unit with a heating and/or cooling system (temperature control unit (19)),

- prefabricated three-dimensional spatial unit with devices for a CIP cleaning (cleaning unit (16)),
 - prefabricated three-dimensional spatial unit for a distribution of media and/or energy and/or communication signals (distribution unit (15)),
 - prefabricated three-dimensional spatial unit for temporarily storing the second material fraction (buffer unit),
 - prefabricated three-dimensional spatial unit for the control of the fermentation plant and/or for communication with an external control center spatially separated from the fermentation plant (control unit (20)),
 - prefabricated three-dimensional spatial unit for the measurement and checking of properties of the starting products, intermediate products and/or end products of the fermentation plant (laboratory unit (22)).
7. Plant according to any one of claims 1 to 6, wherein the control unit (20) is designed to supply data about the state of the media in the fermentation plant and/or of one or more components of the plant to the external control center in real time.
8. Plant according to claim 6 or 7 comprising an external control center.
9. Plant according to claim 8, wherein the control center is designed to simulate the products, media, machines, processes and/or the entire production in the fermentation plant (4) with the aid of the data supplied by the control unit.
10. Plant according to any one of claims 1 to 9, comprising one or more of the following features:
- multiple prefabricated three-dimensional spatial units are arranged next to one another and/or one above the other,
 - multiple prefabricated three-dimensional spatial units are arranged around one or more media containers,
 - multiple prefabricated three-dimensional spatial units are arranged parallel next to one another,
 - one or more prefabricated three-dimensional spatial units are aligned horizontally and/or wherein one or more containers are aligned vertically,

- multiple prefabricated three-dimensional spatial units are arranged in groups next to one another.
11. Plant according to any one of claims 1 to 10, wherein the pre-fermentation unit (7) and/or the main fermentation unit (8) is a tank container or is designed on the basis of a tank container.
 12. Plant according to any one of claims 1 to 11, wherein one or more devices for fermenting have at least one freestanding fermenter.
 13. Plant according to any one of claims 3 to 12, wherein at least one container is a 20-foot container and/or at least one container is a 40-foot container and/or at least one container is a 45-foot container.
 14. Plant according to any one of claims 1 to 13, wherein the prefabricated three-dimensional spatial units are arranged at least partially on foundations.
 15. Plant according to any one of claims 1 to 14, wherein the fermentation plant (4) is placed at least partially on truck spaces for the removal of spent grains or another brewery side stream next to the brewing plant.
 16. Plant according to any one of claims 1 to 15, wherein the outlet is the outlet of a lauter tun for spent grains or the outlet of a spent grain silo.
 17. Plant according to any one of claims 1 to 16, wherein the outlet for the second material fraction of the brewing plant is connected to the inlet for the second material fraction of the fermentation plant (4) via a pipeline (5) and/or a pump and/or a buffer vessel.
 18. Plant according to any one of claims 1 to 17, wherein the device for transporting the second material fraction from the outlet of the brewing plant to the inlet of the fermentation plant (4) comprises one or more transport vehicles.
 19. Plant according to any one of claims 1 to 18, wherein the outlet of the brewing plant is connected to the inlet of the fermentation plant (4) via a buffer vessel which comprises devices for sterilizing the second material fraction.

20. Plant according to any one of claims 1 to 19, wherein the prefabricated three-dimensional spatial unit comprises lines for media and/or energy and/or communication in the upper region and/or one or more interfaces for connecting the lines to further prefabricated three-dimensional spatial units in the outer wall and/or units for production, storage vessels, control devices and/or an electronic data processing system in the lower region.
21. Plant according to any one of claims 1 to 20, wherein the prepared three-dimensional spatial unit has a maximum external width of up to 6.1 m and/or an external height of up to 4.2 m and/or an external length of up to 20 m.