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(54) **COMBUSTOR DRYER**

BRENNKAMMERTROCKNER

SÉCHOIR DE CHAMBRE DE COMBUSTION

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Description

[0001] The invention relates to a combustor dryer, in particular a pulse or pulsed combustor dryer, for dehydration and/or granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres, sugars and/or vegetable starches, and a corresponding method for dehydration and/or granulation of the wet feedstock.

[0002] US 5,015,171 discloses a pulse combustor. US 4,183,145 describes a spray-drying method. CN1180343 relates to a method for treating excrement.

[0003] The term pulse, pulsed (or impulse) combustion (PC) originates from the intermittent (periodic) combustion of air (or another oxidant) with gaseous, liquid or solid fuel. Pulse combustors typically comprise inlet ports to admit combustion air and fuel, a combustion chamber in which the fuel/air mixture is ignited and a resonance tube or tailpipe used to expel the exhaust gases. The continuous stream of hot pulsating gases is then utilised in downstream processes such as heating, atomisation and drying of liquid feedstock.

[0004] Pulse combustion burners have advantages over steady flame combustion burners, e.g. an increased mass and heat transfer rate, an increased combustion intensity and higher energy efficiency with low excess air and reduced pollutant emissions. Disadvantages are a comparatively high noise level (requiring special attenuation measures) and difficulties of controlling (due to interactive process parameters).

[0005] In pulse combustion burners of the prior art, the "pulses" originate inside a combustion chamber at a predetermined frequency of oscillation which is dependent on the speed of sound and the physical relationship between the combustion chamber and tailpipe dimensions in accordance with the Helmholtz formulas. Known pulse combustors used in drying processes operate as Helmholtz resonators where the single (fixed) frequency originating from the combustion chamber is "tuned" primarily by changing the length of the tailpipe.

[0006] The mechanism used in such a pulse combustor to excite oscillations at a specific frequency (or "note") is similar to those used in music instruments such as a flute or by blowing air over the neck of an empty bottle. Here, the frequency of oscillation (or "note") originates inside the cavity of the instrument as a result of its size and shape. The music player blows an even (non-vibrating) air stream over an opening which excites secondary circulating currents or "eddies" which generate acoustic oscillations or "pulses".

[0007] Furthermore, the inventor developed a "pulsed" combustor method in which the combustion air is mechanically excited or (pulsed) at the predetermined frequency externally to and before entering a combustion chamber.

[0008] A burner frequency therefore originates outside the combustion chamber and is not determined by the physical dimensions or operating conditions of either the

combustion chamber or any tailpipe (as in the prior art). The source of oscillations produced by the pulsed combustor is similar to that of a trombone, bugle or a blowing horn (vuvuzela), where the "note" is dictated by the vibrating lips of the player and not by the natural resonance of a cavity. In such cases, the instrument body and its physical shape merely serve to amplify or intensify the acoustic note created by the player's lips. In the field of dehydration and/or granulation, the "pulsed" combustion method according to the present invention allows a simple adjustment of the air pulses, wherein it is not necessary to physically change any dimensions of the combustor or combustor tailpipe (as in the prior art). Hence, the pulsed combustor assembly contributes to an efficient and simple dehydration and/or granulation of wet feedstock.

[0009] The term "air" may be understood as ambient air but should be generally understood as being any gas (mixture) containing oxygen (of at least 5% or at least 20%). The term "beat frequency" (f_3) may be understood as the audible beat frequency being the absolute value of the difference of the frequencies (e.g. f_1, f_2) generating the beat: e.g. $f_3 = |f_1 - f_2|$.

[0010] Particles, generated and dried by a (in particular pulse or pulsed) combustor drying process can be very small so that it can be difficult to remove the dried particles from the process. Moreover, at least some materials to be dried tend to stick together (e.g. at the walls of a drying chamber) which makes it difficult to remove and recover the final product.

[0011] The invention is a combustor dryer according to claim 1, a method according to claim 8 and a use according to claim 10.

[0012] According to a first aspect of the invention, a combustor dryer, in particular a pulse or pulsed combustor dryer, for dehydration and/or granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres, sugars and/or vegetable starches, is proposed. The combustor dryer comprises several (in particular at least a first and a second, optionally in addition at least a third) combustion chambers and a drying chamber, wherein each of the combustion chambers is connected with the drying chamber, wherein the combustor dryer is configured so that an oscillation of gas emerging into the drying chamber from the first combustion chamber is different (or can be controlled to be different) to an oscillation of gas emerging into the drying chamber from the second combustion chamber (in particular at least with respect to an oscillation frequency).

[0013] A core idea of the idea of the invention is to provide several combustor assemblies (combustion chambers) for one and the same drying chamber. The several combustion chambers allow to generate and distribute several streams of the mixture of the combustion gas and the feedstock within the drying chamber over a width (or other dimension) of the drying chamber. Moreover, the overall structure of the combustor dryer can be compacted which simplifies the combustor dryer and a

corresponding drying method. The feedstock may emerge from (combustion chamber driven) atomizers (or nozzles, respectively) between (each of) the several combustion chambers and the drying chamber.

[0014] Since the combustor dryer is configured so that an oscillation of gas emerging into the drying chamber from the first combustion chamber is different (or can be controlled to be different) to an oscillation of gas emerging into the drying chamber from the second combustion chamber (in particular at least with respect to an oscillation frequency and/or a phase), the movement of the product to be dried within the drying chamber can be further modified which enhances the drying efficiency. The oscillation of gas emerging into the drying chamber implies a corresponding oscillation of product particles in the gas.

[0015] The combustor dryer is further configured so that combustion chamber frequencies of an oscillation of gas emerging into the drying chamber from the first combustion chamber (via an atomizer or nozzle, respectively) and of an oscillation of gas emerging into the drying chamber from the second combustion chamber (via an atomizer or nozzle, respectively) are adapted or controlled or controllable so that a beat frequency resulting from the combustion chamber frequencies is generated in the drying chamber. The beat frequency is preferably at least 5 Hz, further preferably at least 10 Hz. The beat frequency may be below 50 Hz, preferably below 30 Hz. The advantage is that comparatively high frequencies in the combustion chambers can efficiently atomize and dehydrate the wet feedstock (e.g. passing through an atomizer or impingement zone, respectively). Nonetheless, by generating the (comparatively low) beat frequency in the drying chamber, the further dehydration in the drying chamber can be improved. In essence, the overall time for dehydration is substantially reduced. Adjusting or controlling the respective frequency preferably implies that a plurality of different frequency values (larger than 0), e.g. at least two or at least five or at least ten different (beat) frequency values can be set (the plurality of values may be a continuum or consist of discrete values).

[0016] An absolute value of the difference of the combustion chamber frequencies of an oscillating gas emerging into the drying chamber from the first combustion chamber and of an oscillating gas emerging into the drying chamber from the second combustion chamber is adapted or controlled or controllable so that it corresponds to at least 0.1 % preferably at least 1 %, further preferably at least 2 % of the value of a lower combustion chamber frequency (among the frequencies of gas emerging into the drying chamber from the first combustion chamber and second combustion chamber, respectively) and/or so it corresponds to not more than 50%, preferably not more than 20% of the value of (said) lower combustion chamber frequency. In essence, the (absolute value of the) difference of combustion chamber frequencies is comparatively small with respect to the value of the combustion chamber frequencies per se. This

means, the comparatively high combustion chamber frequencies can effectively atomize and pre-dehydrate the wet feedstock and the rather comparatively low beat frequency in the drying chamber may contribute to an advantageous movement in the drying chamber for further dehydrating (drying) the wet feedstock. This improves efficiency and reduces time required for the total dehydration process.

[0017] The combustor dryer is further configured so that a (the) first combustion chamber frequency of an oscillation of gas emerging into the drying chamber from the first combustion chamber and/or a (the) second combustion chamber frequency of an oscillation of gas emerging into the drying chamber from the second combustion chamber are adjusted or controlled or controllable to be at least 100 Hz, preferably at least 300 Hz and/or not more than 1000 Hz, preferably not more than 600 Hz.

[0018] An average frequency (i.e. a frequency value obtained by summing up the abovementioned frequencies of an oscillation gas emerging into the drying chamber from the first combustion chamber and the second combustion chamber, respectively divided by the number of combustion chambers) is preferably adjusted or controlled or controllable to be at least 50 Hz, preferably at least 100 Hz, further preferably at least 200 Hz, further preferably at least 450 Hz and/or not more than 800 Hz, preferably not more than 550 Hz.

[0019] A control means for controlling a (the) first combustion chamber frequency of an oscillation of gas emerging into the drying chamber from the first combustion chamber and/or a (the) second combustion chamber frequency of an oscillation of gas emerging into the drying chamber from the second combustion chamber and/or a beat frequency of said frequencies and/or an average frequency of said frequencies may be provided. In addition or alternatively, the control means may be provided for controlling a phase shift between the oscillation of gas emerging into the drying chamber from the first combustion chamber and from the second combustion chamber, respectively. Controlling the respective frequency preferably implies that a plurality of different frequency values (larger than 0), e.g. at least two or at least five or at least ten different frequency values can be set (the plurality of values may be a continuum or consist of discrete values).

[0020] Several combustion chambers (or all of the combustion chambers) may be arranged on the same side of the drying chamber, e.g. on a top side or a bottom side of the drying chamber. Moreover, several combustion chambers (or all combustion chambers) may be arranged on different sides of the drying chamber, e.g. at least one on the top side and at least one on the bottom side.

[0021] Preferably, there are at least two or exactly two combustion chambers for one drying chamber or at least three or exactly three combustion chambers for one drying chamber or at least four or exactly four combustion chambers for one drying chamber.

[0022] Preferably, several (or all of the) combustion

chambers are provided in a side-by-side arrangement, preferably in a line or in a triangular configuration.

[0023] At least one combustion chamber (preferably several of or all of the combustion chambers) and the drying chamber may be connected so that gas from the combustion chamber(s) emerges from a bottom side of the drying chamber (in an upward direction, e.g. in an angle of at least 30° or at least 60° or at least substantially 90° with respect to the horizontal direction). Thereby, product movement and distribution during the drying process in the drying chamber can be further improved. Alternatively (or in addition) at least one combustion chamber (or several of the combustion chambers or all of the combustion chambers) and the drying chamber may be connected so that gas from the combustion chamber emerges from a top side of the drying chamber (in a downward direction, e.g. in an angle of at least 30° or at least 60° or at least substantially 90° with respect to the horizontal direction). Alternatively or in addition at least one combustion chamber (or several of the combustion chambers or all of the combustion chambers) and the drying chamber may be connected so that gas from the combustion chamber emerges from a connecting side of the drying chamber connecting the top side and the bottom side (preferably in a horizontal direction or in an angle of less than 45°, preferably less than 25° with respect to the horizontal direction).

[0024] At least a first combustion chamber and a second combustion chamber may be arranged and connected with a drying chamber such that a first combustion gas stream (with product particles) emerging into the drying chamber from the first combustion chamber and a second combustion gas stream (with product particles) emerging into the drying chamber from the second combustion chamber may be directed in parallel or towards each other (wherein an angle between the directions of emergence is at least 30°, preferably at least 60°, further preferably at least 90° or at least substantially 180°).

[0025] The combustor dryer may comprise at least one fuel supply line, at least one air supply line, and at least one pulsed air generator, wherein the pulsed air generator may be connected to the air supply line for generating at least a first pulsed air stream with a pulse frequency f_{10} entering the combustion chamber. Further preferably, a second air supply line and a second pulsed air generator being connected to the second air supply line are provided and configured to generate a second pulsed airstream with a pulse frequency f_{20} entering the (same) combustion chamber, wherein f_{20} is preferably higher or lower than f_{10} .

[0026] At least a portion (in particular lower portion) of the drying chamber may be a (frusto-) conical portion or a portion within inclined walls (approaching each other). An outlet for the product from the drying chamber may be at the lowest portion of the drying chamber (e.g. an end of a conical or frusto-conical portion) or may be provided on a sidewall (e.g. a sidewall of a portion with inclined walls).

[0027] The several combustion chambers may be provided in a line (e.g. four combustion chambers in a line). Alternatively, the combustion chambers may be arranged in a two-dimensional pattern (e.g. in a rectangular or triangular configuration, preferably three combustion chambers may form a triangle). One of (or several of or all of) the combustion chambers may be arranged in the lowest third of the drying chamber or in the topmost third of the drying chamber or in a middle third of the drying chamber (between an upmost third and the lowest third).

[0028] According to another aspect of the invention, a method for dehydration and/or granulation of a wet feedstock is proposed, in particular a viscous feedstock such as the feedstock containing natural fibres, sugars and/or vegetable starches, preferably utilising the combustor dryer as described above, wherein the method comprises supplying a first, in particular pulsed, combustion gas stream, preferably from a first combustion chamber and a second, in particular pulsed, combustion gas stream, preferably from a second combustion chamber, to the same drying chamber.

[0029] An oscillation of the first combustion gas stream and an oscillation of the second combustion gas stream may differ from each other, in particular with respect to a phase and/or frequency. Further method steps may correspond with functional features as described in the context of the above combustor dryer.

[0030] According to a further aspect of the invention, a use of the pulse combustion dryer as described above for dehydration and/or granulation of a wet feedstock, in particular viscous feedstock such as a feedstock containing natural fibres, is proposed.

[0031] The multiple combustion chambers (combustors) may function (totally) independent from one another. In particular, the multiple combustion chambers share the common volume of the drying chamber (after atomization).

[0032] A phase of the oscillating gas emerging into the drying chamber from the respective combustion chambers may be 360° divided by the number of combustion chambers (per drying chamber). If, for example, two combustion chambers are being used they may emerge (fire) pulses at a maximum of 180° out of phase. If, for example, three burners are used, the phase difference would be 120°. If, for example, four combustions chambers are used, the angle would be 90° (etc.). By controlling the frequency (and phase difference) between the gas streams from the respective combustion chambers (burners), a wide range of "beat frequencies" may be generated which may sweep in intensity as they resonate with the cavity of the drying chamber.

[0033] These sweeping or waves of vibrations in turn may prevent or minimise the collection of fine dry particles on the drying chamber walls (resulting from static or other cohesion forces). This allows improved product recovery without mechanically banging or hammering on the drying chamber walls to dislodge powder built-up.

[0034] If two (or more combustion gas streams) are

emerging into the drying chamber so as to collide with each other, the motion of the product to be dried within the drying chamber can be improved. In particular, it can be possible to provide a rolling motion which improves the drying process and hinders the product from sticking to walls of the drying chamber.

[0035] According to a further independent aspect of the invention (which may be combined with one or more of the aspects above, optionally with only one combustion chamber for the one drying chamber or with several combustion chambers for the one drying chamber), a combustor dryer is proposed, in particular a pulse or pulsed combustor dryer, for dehydration and granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres, sugars and/or vegetable starches, comprising at least one combustion chamber and a drying chamber, wherein the at least one combustion chamber is connected with the drying chamber so that gas from the combustion chamber emerges in a horizontal or in an upward direction (preferably in a direction having an angle of at least 20° or at least 30° or at least 50° with respect to the horizontal direction). Thereby, movement of the product to be dried within the drying chamber can be improved (in particular, a rolling motion can be obtained which further improves the drying process and hinders the product from sticking to walls of the drying chamber).

[0036] If the combustor dryer is configured as pulsed combustor dryer, it comprises preferably at least one fuel supply line, at least one air supply line and at least one pulsed air generator, wherein the pulsed air generator is connected to the air supply line for generating at least a first pulsed airstream with a pulse frequency f_{10} entering the combustion chamber. Further preferably the combustor dryer comprises a second air supply line and a second pulsed air generator being connected to the second air supply line and configured to generate a second pulsed airstream with a pulse frequency f_{20} entering the combustion chamber, wherein f_{20} is preferably higher or lower than f_{10} .

[0037] The combustor dryer preferably comprises further at least one gas outlet, in particular in an upper area of the drying chamber, for exhausting gasses, in particular humid gas (air), from inside the drying chamber.

[0038] With the "pulsed" combustor method according to the invention, the combustion air is mechanically excited (or pulsed) at a predetermined frequency externally to and before entering the combustion chamber. A burner frequency therefore originates outside the combustion chamber and is not determined by the physical dimensions or operating conditions of either the combustion chamber or any tailpipe (as in the prior art). The source of oscillations produced by the pulsed combustor is similar to that of a trombone, bugle or a blowing horn (vuvuzela), where the "note" is dictated by the vibrating lips of the player and not by the natural resonance of a cavity. In such cases, the instrument body and its physical shape merely serve to amplify or intensify the acoustic note cre-

ated by the player's lips. In the field of dehydration and/or granulation, the "pulsed" combustion method allows a simple adjustment of the air pulses, wherein it is not necessary to physically change any dimensions of the combustor or combustor tailpipe (as in the prior art). Hence, the pulsed combustor assembly contributes to an efficient and simple dehydration and/or granulation of wet feedstock.

[0039] The term "air" may be understood as ambient air but should be generally understood as being any gas (mixture) containing oxygen (of at least 5% or at least 20%). The term "beat frequency" (f_3) may be understood as the audible beat frequency being the absolute value of the difference of the frequencies (f_{10} , f_{20}) generating the beat: $f_3 = |f_{10} - f_{20}|$. The pulsed air generator may be configured and connected so that a pulsed air stream is not immediately (i.e. directly at the outlet of the generator) mixed with the fuel (coming from the supply line). For example, a travel distance of the pulsed air before being mixed with the fuel to be combusted may be at least 1 cm, preferably at least 10 cm. Moreover, the pulsed air generator may be configured to actively generate the pulsed air stream, i.e. so that the frequency of the pulsed air stream is adjusted (controlled) by the pulsed air generator or, respectively, a control means of the pulsed air generator (only). This means, the pulsed air generator would not be a mere passive element which reacts on other conditions of the combustion assembly, such as a low pressure portion of a combustion cycle.

[0040] Preferably, the pulsed combustor assembly comprises a second air supply line and a second pulsed air generator being connected to the second air supply line and configured to generate a second pulsed air stream with a pulse frequency f_{20} entering the combustion chamber. The second air supply line and/or the second pulse air generator may be structured and/or configured and/or arranged similar to or identical to the first air supply line and/or first pulsed air generator, respectively. The frequency f_{20} is preferably higher or lower than f_{10} . By this, the adjustment of the frequency within the combustion chamber is further improved. The frequency f_{10} and/or the frequency f_{20} may be adjustable. A control means may be provided for adjusting the frequency f_{10} within a predetermined range and/or for adjusting the frequency f_{20} within a predetermined range. "Adjusting the frequency" preferably, means that a plurality of frequencies (larger than 0) can be set (the plurality of values may be a continuum or consist of discrete values). The control means can function as an open loop or closed loop control. A first control means may be provided for controlling f_{10} . A second control means may be provided for controlling f_{20} . One control means may be provided for controlling both f_{10} and f_{20} . In any case, the adjustment possibilities are further improved so that the pulsed combustor assembly may contribute for a more efficient dehydration and/or granulation of a wet feedstock.

[0041] The first and/or second pulsed air generator may comprise an (in particular motorised) air interrupter.

The air interrupter may comprise a rotating disk, lobe and/or valve assembly. Thereby, the pulse generation is executed in a simple way.

[0042] The first air supply line and the second air supply line may be connected to a common compressed air supply line (preferably being part of the pulsed combustor assembly). The pulsed combustor assembly may further comprise a source for compressed air.

[0043] Preferably, the frequencies f_{10} and f_{20} are adjusted (in particular by the control means) to generate a beat frequency f_{30} within the combustion chamber. In general, the frequencies f_{10} and f_{20} may have a similar (but not identical) value. For example, f_{20} may be at least 1% or at least 3% higher and/or less than 30% or less than 15% higher than the frequency f_{10} . If there is only a small difference between the frequencies f_{10} and f_{20} , a beat frequency f_{30} will be generated. A "beat" is an interference phenomenon between two waves (sounds) of slightly different frequencies. This interference results in a waveform comprising a high frequency component which is (at least approximately) the average frequency between f_{10} and f_{20} and a beat frequency which results from the envelope of the higher frequency component. The beat frequency is (at least approximately) the difference between the frequencies f_{10} and f_{20} . Energy from the high-frequency components may be utilised both to atomise and dehydrate the wet feedstock passing through an impingement zone. On the other hand, the low beat frequency may pass through the combustion chamber and enhance the dehydration in a drying chamber arranged downstream. Thereby, the efficiency of the dehydration process is improved. In particular, the time for dehydration is reduced and a comparatively small drying chamber can be used.

[0044] Preferably, the control means is configured to simultaneously vary the frequencies f_{10} and f_{20} within a predetermined frequency range, wherein a difference $f_{10} - f_{20}$ is preferably at least substantially constant for generating an at least substantially constant beat frequency f_{30} . The frequency range (within which f_{10} and f_{20} may be varied) can be for example 100 to 600 Hz, preferably 300 to 500 Hz. Thereby, a high band of frequencies may be generated containing both odd and even harmonics of an average frequency $f_{40} = (f_{10} + f_{20})/2$, while the low beat frequency f_{30} may preferably remain (effectively) unchanged (if f_{30} is constant). The difference $f_{10} - f_{20}$ can be between 10 Hz and 30 Hz, in particular 20 Hz. Advantageously, the average frequency f_{40} is adapted to current process parameters, in particular the temperature within the combustion chamber. Thereby, resonance conditions can be adjusted (which are dependent on the speed of sound being dependent on the temperature). Preferably, a temperature determining means is provided for determining the temperature within the combustion chamber. The control means may control f_{10} and f_{20} based on the temperature.

[0045] The compressed air (modulated by f_{10} and f_{20}) may be mixed with fuel. The mixture may be ignited by

an ignition source inside the combustion chamber.

[0046] In general, f_{10} and/or f_{20} may be more than 100 Hz, preferably more than 300 Hz and/or less than 600 Hz, preferably less than 500 Hz. An average frequency $f_{40} = (f_{10} + f_{20})/2$ may be more than 300 Hz and/or less than 500 Hz. The beat frequency f_{30} may be more than 10 Hz and/or less than 30 Hz.

[0047] The frequencies f_{10} and f_{20} are preferably adjusted (in particular by the control means) such that the fundamental frequency and/or odd and/or even harmonics of an average frequency $f_{40} = (f_{10} + f_{20})/2$ resonate with the combustion chamber. In particular, a high frequency band (with a fundamental frequency e.g. between 300 to 500 Hz) as defined by f_{10} and f_{20} may be adjusted to resonate with a comparatively small (regarding its volume or acoustical length, respectively) combustion chamber while the (low) beat frequency f_{30} (typically at least approximately 30 Hz) passes through the combustion chamber and resonates with a comparatively large (regarding its volume or acoustical length, respectively) drying chamber.

[0048] The pulsed combustion (continuous pulsed combustion) in the combustion chamber may generate a stream of high-temperature exhaust gases which exit at a high velocity (for example, 100 m/s) via a nozzle. The mass and inertia of the high-temperature, oscillating exhaust gas may form a conduit (waveguide) on which both a high and a low-frequency acoustic shockwave may be super-imposed. Such conduit may additionally channel acoustic energy at "screech" frequencies, as well as a broadband of harmonic frequencies generated inside the combustion chamber, towards an impingement zone.

[0049] The frequencies f_{10} and f_{20} may be adjusted (in particular by the control means) such that the combustion chamber functions as a low pass filter absorbing the average frequency $f_{40} = (f_{10} + f_{20})/2$, wherein the beat frequency f_{30} passes preferably (substantially) unchanged. In particular, the average frequency stays within the combustion chamber. In particular, acoustic pulses at the beat frequency f_{30} , generated in the combustion chamber, may be too low to excite acoustic resonance in the cavities of the (small volume) combustion chamber and pass through the combustion chamber (and preferably through a shear atomizer downstream of the combustion chamber) to find resonance in the (large volume) drying chamber. In general, the combustion chamber may behave like a low-pass filter for the beat frequency f_{30} .

[0050] According to another aspect of the present invention, a pulsed combustion dryer for dehydration and/or granulation of a wet feedstock, in particular viscous feedstock such as a feedstock containing natural fibres, sugars and/or vegetable starches, comprises a pulsed combustor assembly as described above.

[0051] The combustion dryer (in particular pulse or pulsed combustion dryer) may comprise an atomizer (preferably for each combustion chamber). The combus-

tion dryer (in particular pulse or pulsed combustion dryer) may comprise a drying chamber. A volume of a drying chamber may be larger than a volume of the combustion chamber. Preferably, the volume of the drying chamber is at least 50 times, further preferably at least 100 times, even further preferably at least 300 times, e.g. 600 times as large the volume of the combustion chamber. The volume of the drying chamber may be less than 1000 times the volume of the combustion chamber, preferably less than 800 times, further preferably less than 600 times. An acoustic length of the drying chamber may be at least 5 times, further preferably at least 10 times, even further preferably at least 30 times as long as an acoustic length of the combustion chamber. The (pulse or pulsed) combustion dryer may comprise a granulator, preferably fluid bed granulator, in particular spouted bed granulator. The resonance frequency of the combustion chamber may be at least 2 times, preferably at least 3 times, further preferably, at least 4 times, even further preferably at least 6 times as large as the resonance frequency of the drying chamber. The granulator (spouted bed granulator) may comprise a free board area (= area between a top surface of a bed of the granulator and a nozzle where the feedstock emerges).

[0052] It is preferred that the beat frequency f_{30} resonates with the drying chamber. In general, it is possible to induce (or excite) acoustic resonance in both cavities (the combustion chamber and the drying chamber) even if they have two different sizes. This is achieved by "mixing" the frequencies f_{10} and f_{20} and generating the beat frequency f_{30} . Thereby, it is possible not only to have acoustic pulses in the combustion chamber (as in principle also in the prior art) but at the same time, also in the (large volume) drying chamber. Thereby, the dehydration and/or granulation can be realised in a more efficient way, in particular faster.

[0053] According to another aspect of the invention, a method for dehydration and/or granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres, sugars and/or vegetable starches, preferably utilising the pulsed combustor assembly of the pre-described kind and/or the pulsed combustion dryer of the pre-described kind, comprises a supply of fuel via a fuel supply line and a supply of a first pulsed air stream with a pulse frequency f_{10} via a first air supply line to a combustion chamber. The method may further comprise supplying a second pulsed air stream via a second air supply line with a pulse frequency f_{20} to the combustion chamber, wherein f_{20} is preferably higher or lower than f_{10} . The method may comprise the further steps of adjusting (controlling) f_{10} and f_{20} so that an average frequency $f_{40} = (f_{10} + f_{20})/2$ resonates with the combustion chamber. The average frequency may stay in the combustion chamber. A beat frequency f_{30} (of f_{10} and f_{20}) may pass through the combustion chamber and may preferably resonate with a drying chamber. The method may contain further features according to the functional features being described with respect to

the pulsed combustor assembly and/or the pulsed combustion dryer above.

[0054] Another aspect of the invention is a use of the combustion dryer of the pre-described kind for dehydration and/or granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres. The pulsed combustor assembly and/or the pulsed combustion dryer and/or the method for dehydration and/or granulation may be applied for dehydration (drying) and simultaneously producing granular products, for example from (pumpable) pastes, slurries and/or (smoothie-like) purees, in particular derived from (whole) fruits and/or vegetables (e.g. as used in the food and/or beverage industry sectors). Further applications may be other (paste-like) feedstock such as meat, fish and/or dairy products (e.g. including viscous polymers, minerals and/or chemicals).

[0055] In general, a size of the (spherical) granules obtained by the combustor dryer and/or method of the present invention may vary between 1.0 and 5.0 millimetres.

[0056] The enclosed figures show embodiments and (further) aspects of the invention. In particular, the figures show:

- Fig. 1: a first embodiment of a combustor dryer in a perspective view;
- Fig. 2: the combustor dryer of Fig. 1 in a side view;
- Fig. 3: the combustor dryer of Fig. 1 in a top view;
- Fig. 4: a perspective view of a second embodiment of a combustor dryer according to the invention;
- Fig. 5: a side view of the combustor dryer of Fig. 4;
- Fig. 6: a top view of the combustor dryer of Fig. 4;
- Fig. 7: a perspective view of a further embodiment of a combustor dryer according to the invention;
- Fig. 8: a side view of the combustor dryer of Fig. 7;
- Fig. 9: a bottom view of the combustor dryer of Fig. 7;
- Fig. 10: a further embodiment of a combustor dryer according to the invention;
- Fig. 11: a side view of the embodiment of Fig. 10;
- Fig. 12: a top view of the embodiment of Fig. 10;
- Fig. 13: a schematic of a combustor dryer according to the invention.

[0057] Figs. 1 to 3 show a first embodiment of a combustor dryer according to the invention. The combustor dryer comprises a drying chamber 10 and several (three) combustion chambers 11a, 11b and 11c being connected to the (one) drying chamber 10. Between the drying chamber 10 and each of the combustion chambers 11a, 11b and 11c, a (shear) atomizer and/or a corresponding nozzle may be provided for finely dividing the wet feedstock before being (further) dehydrated on its way to a product outlet 12. The several (three) atomizers and/or nozzles can be arranged as it is schematically illustrated in Fig. 13 for one (shear) atomizer and nozzle.

[0058] The drying chamber 10 comprises a cylindrical portion 13 and a conical portion 14, wherein the product outlet 12 is provided at the bottom of the conical portion 14. Each of the combustion chambers 11a, 11b and 11c can be provided with (pressurised) air and fuel so that a pulse or pulsed combustion can be achieved. In this regard, corresponding supply lines may be provided for each combustion chamber or one corresponding supply line may be provided which branches off, whereby branches lead to the combustion chambers.

[0059] The embodiment of Figs. 4 to 6 correspond with the embodiment of Figs. 1 to 3 with the exception of the arrangement of the several (three) combustion chambers. The combustion chambers in Figs. 4 to 6 are arranged on a sidewall 15, in particular the cylindrical portion 13 of the drying chamber 10. In this case, the combustion chambers 11a, 11b and 11c are arranged along a circumference of the drying chamber at an angular distance of (at least approximately) 120°. The combustion chambers 11a-11c are arranged at and connected with the drying chamber so that a gas-product-mixture emerges in directions 16a, 16b, 16c, respectively (see Fig. 6) wherein an angle between these directions is (approximately) 120°. Thereby, an advantageous movement (rolling motion) of the product may be achieved.

[0060] Figs. 7 to 9 show a further embodiment of the combustor dryer of the invention. In agreement with the embodiments of Figs. 1 to 3 and 4 to 6, respectively, the combustor dryer comprises a combustion chamber 10 with a cylindrical portion 13 and a conical portion 14. Between the conical portion 14 and the cylindrical portion 13, a frusto-conical portion 17 is provided which has optionally an inclination which is less steep than the inclination of the conical portion 14.

[0061] In the frusto-conical portion 17, the combustion chambers 11a, 11b and 11c are connected to the drying chamber 10. In a projection on a horizontal plane, respective directions 16a, 16b and 16c of the gas-product-mixture emerging into the drying chamber 10 from the combustion chambers 11a, 11b and 11c (optionally via an atomizer) with a respective angle of 120°. With respect to the horizontal plane, the directions 16a, 16b and 16c have an angle of between (approximately) 20° to 45° (see Fig. 8). In the embodiment of Figs. 7 to 9, the gas-product-mixture emerges (is fired or projected) in an upward direction which efficiently minimizes sticking of the product to the wall of the drying chamber 10.

[0062] Figs. 10 to 12 show a further embodiment of the combustor dryer. A combustion chamber 10 of the combustor dryer comprises a portion 18 with parallel walls (where two opposing pairs of walls are parallel with each other) and a portion with inclined walls 19. The product outlet 12 is provided at a lower end of one or more of the inclined walls of portion 19. The cross-section of the drying chamber 10 (from the top to the bottom) may be either square or rectangular, wherein a length of the rectangle may be at least 1.5 times as large as a width of the rectangle. In contrast to Figs. 1 to 9, all combustion cham-

bers 11a, 11b, 11c and 11d are arranged in a line (side-by-side).

[0063] In all embodiments, in particular in the conical portion of the embodiments according to Figs. 1 to 9 or in the portion with inclined walls of the embodiment of Figs. 10 to 12, a fluidised, in particular spouted bed granulator may be provided with one or more openings for providing (spouting) air. This further reduces the risk of product sticking to the walls of the drying chamber 10.

[0064] Fig. 13 shows a further embodiment of a combustor dryer according to the invention.

[0065] The apparatus comprises a pulsed combustor assembly A for generating a (continuous) stream of high-temperature sonic pulses. Combustor assembly A is coupled to a shear atomizer B. The shear atomizer B finely divides the wet feedstock before being dehydrated on its way to an (integrated) spouted bed granulator C. In Fig. 13, only one combustor assembly A and shear atomizer B is shown. However, it is preferred that at least two combustor assemblies A and corresponding shear atomizers B are provided (for one drying chamber or spouted bed granulator C, respectively).

[0066] The spouted bed granulator C produces and delivers the final product as, in particular powders, granules or melts. The pulsed combustor assembly A and shear atomizer B may require less than 10 milliseconds for removing more than 90% of the product's moisture. The balance may be removed in the spouted bed granulator C.

[0067] The combustor assembly A is "externally" pulsed using two motorised air interrupters 113 and 114, which are both connected to a common compressed air supply 115 via a first and a second air supply line 126, 127. The compressed air supply provides sufficient energy for generating a stream of (sharp) acoustic pulses (or shockwaves) when the air passes through the air interrupters 113 and 114 in the direction of a combustion chamber 116. In the combustion chamber 116, the air is utilised for combustion and optionally as excess air.

[0068] A fuel supply line 123 provides fuel to the combustion chamber 116. The fuel is ignited by an ignition source 124. An inlet 21 is provided for supplying feedstock to the apparatus. Via an outlet 122, humid air and gas emerges from the drying chamber 117. Inlet 121 provides the spouting air source. The granulated product may emerge from an outlet 120.

[0069] The interrupters 113 and 114 may comprise a (motorised) rotating disk, lobe or valve assembly where a ported or shaped element rotates in (close) proximity to a stationary element. Ports may periodically interact or align with one another, thereby releasing a burst of pulsed air into the combustion chamber 116. Rotating the (motorised) interrupters 113 and 114 at a high speed generates two distinct (high-pitch, siren-like) tones at frequencies f10 and f20 respectively, where frequencies f10 and f20 are directly proportional to the motor speeds of the interrupters 113 and 114. Combining the two frequencies f10 and f20 in the combustion chamber 116 produces

a distinct third, low beat frequency at a beat frequency f_{30} corresponding to (or at least closely approximating) the difference between the frequencies f_{10} and f_{20} . By simultaneously varying the speeds of air interrupters 113 and 114 with a constant speed difference, corresponding to f_{30} , a band of frequencies may be generated, defined by f_{10} and f_{20} without affecting the beat frequency f_{30} . This high band of frequencies may contain both odd and even harmonic components of frequencies f_{10} and f_{20} , while the low (fundamental) frequency f_{30} remains effectively unchanged.

[0070] The high-frequency band (between 300 and 500 Hz), as defined by f_{10} and f_{20} , is adjusted to resonate with the (small volume) combustion chamber 116 while the low-frequency component f_{30} (at least approximately 30 Hz) passes through the combustion chamber 116 to resonate with a (larger volume) drying chamber 117.

[0071] Continuous pulsed combustion in the combustion chamber 116 generates a stream of high-temperature exhaust gases which exit from chamber 116 at high velocity (above 100 m/s) via a nozzle 118. The mass and inertia of the high-temperature, oscillating exhaust gases form a conduit or waveguide on which both high and low-frequency acoustic shockwaves are super-imposed. This conduit may channel a broadband of harmonic frequencies generated inside the combustion chamber (as well as acoustic energy at screech frequencies), towards an impingement zone 119.

[0072] Energy from the high-frequency (e.g. 300 to 500 Hz) and (optionally) screech frequency components of the hot pulsed gas stream is utilised both to atomise and dehydrate wet feedstock passing through the shear atomizer B into the impingement zone 119, while the low beat frequency component of e.g. 10 to 30 Hz is "tuned" to resonate with the (large-volume) drying chamber 117. The (acoustic) pulses at the beat frequency f_{30} , generated in the pulsed combustor assembly A are generally too low to excite low acoustic resonance in the cavities of the (small-volume) combustion chamber 116 and pass through both the combustion chamber 116 and the shear atomizer B to find resonance in the (larger volume) drying chamber 117 forming a free board area of the spouted bed granulator C. Therefore, combustion chamber 116 behaves like a low pass filter for the beat frequency f_{30} .

[0073] The following example further illustrates the effects and functions of the apparatus (the values are not necessarily limiting). If f_{10} is 430 Hz and f_{20} is 450 Hz, the beat frequency f_{30} is 20 Hz. The combustion chamber may be tuned to the odd and even half wavelength integers corresponding to the average frequency of 440 Hz falling midway between 430 Hz and 450 Hz. The beat frequency of 20 Hz, however, falls outside this resonance band due to its long acoustic wavelength.

[0074] The harmonics of the average frequency originating from the two high-frequency (shortwave length) shockwaves are used to atomize liquid feedstock while the high temperature component driven by the combustion gases is used to dehydrate the feedstock droplets

formed during atomisation. The (low-frequency, long wavelength) beat frequency f_{30} (derived from f_{10} and f_{20}) is used to enhance dehydration in the downstream drying chamber 117.

[0075] The apparatus allows the generation of both high temperatures (600 to 800°C) and high frequency (100 to 500 Hz) acoustic shockwaves for atomizing and partly dehydrating liquid feedstock. The atomization and partial dehydration may require less than 0.1 seconds depending on the thermal efficiency of the pulse combustor. High viscosity slurries (as for example in the fruit and vegetable industries) typically require higher acoustic energy and longer atomization times. According to the prior art, usually a "post-atomization" thermal energy and comparatively long retention times are required for total dehydration. According to the present invention, thermal drying is partly replaced by acoustic drying which greatly reduces energy and product retention times and improves product quality and taste.

[0076] In particular, the apparatus creates improved sonic conditions inside the drying chamber in order to enhance the removal of residual moisture from the atomized droplets (aerosols) at lower temperatures and shorter product retention times.

[0077] In the prior art, most or all of the thermal and sonic energy is spent, after product atomization and partial dehydration leaving little or no acoustic energy for further dehydration inside the downstream drying chamber. The present apparatus, however, allows subjecting the aerosols in the drying chamber to (longitudinal and/or transverse) sonic waves, which may be tuned to resonate with the drying chamber cavity. These high-energy pressure and partial vacuum pulses based on the low beat frequency f_{30} accelerate mass transfer (moisture evaporation), thereby allowing a reduction of both chamber temperature and product retention times.

[0078] Because the two frequencies f_{10} and f_{20} are provided, it is possible to have a low fundamental frequency (of 10 to 30 Hz) within the drying chamber which would not be possible with a single frequency provided to the combustion chamber.

Reference numerals

[0079]	
A	Pulse combustor assembly
B	Shear atomizer
C	Spouted bed granulator
10	Drying chamber
11a	Combustion chamber
11b	Combustion chamber
11c	Combustion chamber
11d	Combustion chamber
12	Product outlet
13	Cylindrical portion
14	Conical portion
15	Sidewall

16a Direction
 16b Direction
 16c Direction
 17 Frusto-conical portion
 18 Portion with parallel walls
 19 Portion with inclined walls
 113 First air interrupter
 114 Second air interrupter
 115 Compressed air supply
 116 Combustion chamber
 117 Drying chamber
 118 Nozzle
 119 Impingement zone
 120 Outlet for granulated products
 121 Inlet for spouting air
 122 Outlet for humid air and gas
 123 Fuel supply line
 124 Ignition
 125 Inlet for feedstock
 126 First air supply line
 127 Second air supply line

Claims

1. A combustor dryer, in particular a pulse or pulsed combustor dryer, for dehydration and/or granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres, sugars and/or vegetable starches, comprising several, in particular at least a first (11a) and a second (11b), combustion chambers (11a-11d) and a drying chamber (10),
 wherein the combustion chambers (11a-11d) are connected with the drying chamber (10); wherein the combustor dryer is configured so that an oscillation of gas emerging into the drying chamber (10) from the first combustion chamber (11a) is different, or can be controlled to be different, to an oscillation of gas emerging into the drying chamber (10) from the second combustion chamber (11b), at least with respect to an oscillation frequency,
 wherein the combustor dryer is further configured so that a first combustion chamber frequency f1 of the oscillation of gas emerging into the drying chamber (10) from the first combustion chamber (11a) and/or a second combustion chamber frequency f2 of an oscillation of gas emerging into the drying chamber (10) from the second combustion chamber (11b) are adjusted or controlled or controllable to at least 100 Hz, preferably at least 200 Hz and/or not more than 1000 Hz, preferably not more than 600 Hz,
 wherein the combustor dryer is further configured so that combustion chamber frequencies f1 and f2 respectively of the oscillation of gas emerging into the drying chamber (10) from the first combustion chamber (11a) and of the oscillation of gas emerging into the drying chamber (10) from the second combustion

chamber (11b) are adapted or controlled or controllable so that a beat frequency f3 resulting from the combustion chamber frequencies f1 and f2 is generated in the drying chamber, wherein the beat frequency f3 is the absolute value of the difference of combustion chamber frequencies f1 and f2 respectively of the oscillating gas emerging into the drying chamber (10) from the first combustion chamber (11a) and of the oscillating gas emerging into the drying chamber from the second combustion chamber (11b), wherein the beat frequency is at least 10 Hz and less than 30 Hz,
 wherein the beat frequency f3 is adapted or controlled or controllable so that it corresponds to at least 0.1 %, preferably at least 1 %, further preferably at least 2 % of the value of a lower combustion chamber frequency and/or so that it corresponds to not more than 50 %, preferably not more than 20 % of the value of the lower combustion chamber frequency,
 and wherein the combustor dryer comprises control means for controlling the first combustion chamber frequency f1 of the oscillation of gas emerging into the drying chamber (10) from the first combustion chamber (11a) and/or the second combustion chamber frequency f2 of the oscillation of gas emerging into the drying chamber (10) from the second combustion chamber (11b) and/or the beat frequency f3 of said frequencies f1 and f2 and/or an average frequency $f_4 = (f_1 + f_2)/2$ of said frequencies f1 and f2.

2. The combustor dryer of claim 1, **characterised in that** the combustor dryer is configured so that an oscillation of gas emerging into the drying chamber (10) from the first combustion chamber (11a) is different, or can be controlled to be different, to an oscillation of gas emerging into the drying chamber (10) from the second combustion chamber (11b), at least with respect to an oscillation phase.

3. The combustor dryer of one of the preceding claims, **characterised in that** several combustion chambers (11a-11d) are arranged on the same side of the drying chamber (10), e.g. on a top side or a bottom side, and/or **characterised in that** several combustion chambers (11a-11d) are arranged on different sides of the drying chamber, e.g. at least one on the top side and at least one on the bottom side.

4. The combustor dryer of one of the preceding claims, **characterised in that** at least one combustion chamber (11a-11d) and the drying chamber (10) are connected so that gas from the combustion chamber (11a-11d) emerges from a bottom side of the drying chamber (10) and/or
 at least one combustion chamber (11a-11d) and the drying chamber (10) are connected so that gas from the combustion chamber emerges from a top side of the drying chamber (10) and/or

at least one combustion chamber (11a-11d) and the drying chamber (10) are connected so that gas from the combustion chamber (11a-11d) emerges from a connecting side of the drying chamber (10) connecting the top and bottom side.

5. The combustor dryer of one of the preceding claims, **characterised in that** at least a first combustion chamber (11a) and a second combustion chamber (11b) are arranged and connected with a drying chamber such that a first combustion gas stream, with product particles, emerging into the drying chamber (10) from the first combustion chamber and a second combustion gas stream, with product particles, emerging into the drying chamber from the second combustion chamber are directed towards each other, wherein an angle between the directions of emergence is at least 30°, preferably at least 60°, further preferably at least 90° or at least substantially 180°.
6. The combustor dryer of one of the preceding claims, **characterised by** at least one fuel supply line (123), at least one air supply line (126), and at least one pulsed air generator, wherein the pulsed air generator is connected to the air supply line (126) for generating at least a first pulsed air stream with a pulse frequency f10 entering the combustion chamber (116), preferably further **characterized by** a second air supply line (127) and a second pulsed air generator being connected to the second air supply line (127) and configured to generate a second pulsed air stream with a pulse frequency f20 entering the combustion chamber, wherein f20 is preferably higher or lower than f10.
7. A combustor dryer of one of the preceding claims, wherein the combustion chambers (11a-11d) are connected with the drying chamber (10) so that gas from the combustion chamber emerges in a horizontal or in an upward direction.
8. A method for dehydration and/or granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres, sugars and/or vegetable starches, utilizing the combustor dryer of one of the claims 1 to 7, comprising supplying a first combustion gas stream, preferably from a first combustion chamber (11a) and a second combustion gas stream, preferably from a second combustion chamber (11b), to the same drying chamber (10), an oscillation of the first combustion gas stream and an oscillation of the second combustion gas stream differs from each other, with respect to a frequency.
9. The method of claim 8, **characterized in that** an oscillation of the first combustion gas stream and an

oscillation of the second combustion gas stream differs from each other, in particular with respect to a phase.

10. A use of the combustor dryer of one of the claims 1 to 7 for dehydration and/or granulation of a wet feedstock, in particular a viscous feedstock such as a feedstock containing natural fibres.

Patentansprüche

1. Brennkammertrockner, insbesondere ein Puls- oder gepulster Brennkammertrockner, für Dehydrierung und/oder Granulierung eines nassen Rohmaterials, insbesondere eines viskosen Rohmaterials wie eines Rohmaterials, das Naturfasern, Zucker und/oder Pflanzenstärken enthält, umfassend mehrere, insbesondere mindestens eine erste (11a) und eine zweite (11b), Brennkammern (11a-11d) und eine Trockenkammer (10), wobei die Brennkammern (11a-11d) mit der Trockenkammer (10) verbunden sind; wobei der Brennkammertrockner konfiguriert ist, sodass sich eine Oszillation von Gas, das aus der ersten Brennkammer (11a) in die Trockenkammer (10) austritt, von einer Oszillation von Gas, das aus der zweiten Brennkammer (11b) in die Trockenkammer (10) austritt, mindestens bezüglich einer Oszillationsfrequenz unterscheidet, oder gesteuert werden kann, um sich davon zu unterscheiden, wobei der Brennkammertrockner ferner konfiguriert ist, sodass eine erste Brennkammerfrequenz f1 der Oszillation des Gases, das aus der ersten Brennkammer (11a) in die Trockenkammer (10) austritt und/oder eine zweite Brennkammerfrequenz f2 einer Oszillation des Gases, das aus der zweiten Brennkammer (11b) in die Trockenkammer (10) austritt, angepasst oder gesteuert oder steuerbar sind, mindestens 100 Hz zu betragen, vorzugsweise mindestens 200 Hz und/oder nicht mehr als 1000 Hz, vorzugsweise nicht mehr als 600 Hz, wobei der Brennkammertrockner ferner konfiguriert ist, sodass die Brennkammerfrequenzen f1 bzw. f2 der Oszillation des Gases, das aus der ersten Brennkammer (11a) in die Trockenkammer (10) austritt, und der Oszillation des Gases, das aus der zweiten Brennkammer (11b) in die Trockenkammer (10) austritt, angepasst oder gesteuert oder steuerbar sind, sodass eine Taktfrequenz f3, die sich aus den Brennkammerfrequenzen f1 und f2 ergibt, in der Trockenkammer erzeugt wird, wobei die Taktfrequenz f3 der Absolutwert der Differenz der Brennkammerfrequenzen f1 bzw. f2 des oszillierenden Gases, das aus der ersten Brennkammer (11a) in die Trockenkammer (10) austritt, und des oszillierenden Gases, das aus der zweiten Brennkammer (11b) in die Trockenkammer austritt, ist,

wobei die Taktfrequenz mindestens 10 Hz und weniger als 30 Hz beträgt,

wobei die Taktfrequenz f_3 angepasst oder gesteuert oder steuerbar ist, sodass sie mindestens 0,1 %, vorzugsweise mindestens 1 %, noch besser mindestens 2 % des Werts einer unteren Brennkammerfrequenz entspricht, und/oder sodass sie nicht mehr als 50 %, vorzugsweise nicht mehr als 20 % des Werts der unteren Brennkammerfrequenz beträgt, und wobei der Brennkammertrockner Steuermittel umfasst, um die erste Brennkammerfrequenz f_1 der Oszillation des Gases, das aus der ersten Brennkammer (11a) in die Trockenkammer (10) austritt und/oder der zweiten Brennkammerfrequenz f_2 der Oszillation des Gases, das aus der zweiten Brennkammer (11b) in die Trockenkammer (10) austritt, und/oder die Taktfrequenz f_3 der Frequenzen f_1 und f_2 und/oder eine Durchschnittsfrequenz $f_4 = (f_1 + f_2)/2$ der Frequenzen f_1 und f_2 zu steuern.

2. Brennkammertrockner nach Anspruch 1, **dadurch gekennzeichnet, dass** der Brennkammertrockner konfiguriert ist, sodass sich eine Oszillation von Gas, das aus der ersten Brennkammer (11a) in die Trockenkammer (10) austritt, von einer Oszillation von Gas, das aus der zweiten Brennkammer (11b) in die Trockenkammer (10) austritt, mindestens bezüglich einer Oszillationsphase unterscheidet, oder gesteuert werden kann, um sich davon zu unterscheiden.
3. Brennkammertrockner nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** mehrere Brennkammern (11a-11d) auf derselben Seite der Trockenkammer (10) angeordnet sind, z. B. auf einer oberen Seite oder einer unteren Seite, und/oder **dadurch gekennzeichnet, dass** mehrere Brennkammern (11a-11d) an verschiedenen Seiten der Trockenkammer angeordnet sind, z. B. mindestens einer an der oberen Seite und mindestens einer an der unteren Seite.
4. Brennkammertrockner nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** mindestens eine Brennkammer (11a-11d) und die Trockenkammer (10) verbunden sind, sodass Gas aus der Brennkammer (11a-11d) von einer Unterseite der Trockenkammer (10) austritt und/oder mindestens eine Brennkammer (11a-11d) und die Trockenkammer (10) verbunden sind, sodass Gas aus der Brennkammer von einer Oberseite der Trockenkammer (10) austritt und/oder mindestens eine Brennkammer (11a-11d) und die Trockenkammer (10) verbunden sind, sodass Gas aus der Brennkammer (11a-11d) von einer Verbindungsseite der Trockenkammer (10) austritt, die die Ober- und Unterseite verbindet.
5. Brennkammertrockner nach einem der vorherge-

henden Ansprüche, **dadurch gekennzeichnet, dass** mindestens eine erste Brennkammer (11a) und eine zweite Brennkammer (11b) angeordnet und mit einer Trockenkammer verbunden sind, sodass ein erster Verbrennungsgasfluss mit Produktpartikeln, der aus der ersten Brennkammer in die Trockenkammer (10) austritt, und ein zweiter Verbrennungsgasfluss mit Produktpartikeln, der aus der zweiten Brennkammer in die Trockenkammer austritt, aufeinander zu gerichtet sind, wobei ein Winkel zwischen den Austrittsrichtungen mindestens 30° beträgt, vorzugsweise mindestens 60°, noch besser mindestens 90° oder mindestens im Wesentlichen 180°.

6. Brennkammertrockner nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** mindestens eine Brennstoffzuleitung (123), mindestens eine Luftzuleitung (126) und mindestens einen pulsierten Luftgenerator, wobei der pulsierte Luftgenerator mit der Luftzuleitung (126) verbunden ist, um mindestens einen ersten pulsierten Luftfluss mit einer Pulsfrequenz f_{10} zu erzeugen, der in die Brennkammer (116) eintritt, vorzugsweise ferner **gekennzeichnet durch** eine zweite Luftzuleitung (127) und einen zweiten pulsierten Luftgenerator, der mit der zweiten Luftzuleitung (127) verbunden ist und konfiguriert ist, einen zweiten pulsierten Luftfluss mit einer Pulsfrequenz f_{20} zu erzeugen, der in die Brennkammer eintritt, wobei f_{20} vorzugsweise höher oder niedriger als f_{10} ist.
7. Brennkammertrockner nach einem der vorhergehenden Ansprüche, wobei die Brennkammern (11a-11d) mit der Trockenkammer (10) verbunden sind, sodass Gas von der Brennkammer in horizontaler Richtung oder aufwärts austritt.
8. Verfahren zur Dehydrierung und/oder Granulierung eines nassen Rohmaterials, insbesondere eines viskosen Rohmaterials wie etwa eines Rohmaterials, das Naturfasern, Zucker und/oder Pflanzenstärken enthält, unter Verwendung des Brennkammertrockners eines der Ansprüche 1 bis 7, umfassend die Zufuhr eines ersten Verbrennungsgasflusses, vorzugsweise aus einer ersten Brennkammer (11a), und eines zweiten Verbrennungsgasflusses, vorzugsweise aus einer zweiten Brennkammer (11b), an die Trockenkammer (10), wobei sich eine Oszillation des ersten Verbrennungsgasflusses und eine Oszillation des zweiten Verbrennungsgasflusses voneinander bezüglich einer Frequenz unterscheiden.
9. Verfahren nach Anspruch 8, **dadurch gekennzeichnet, dass** sich eine Oszillation des ersten Verbrennungsgasflusses und eine Oszillation des zweiten Verbrennungsgasflusses voneinander insbe-

sondere bezüglich einer Phase unterscheiden.

10. Verwendung des Brennkammertrockners nach einem der Ansprüche 1 bis 7 zur Dehydrierung und/oder Granulierung eines nassen Rohmaterials, insbesondere eines viskosen Rohmaterials, wie etwa eines Rohmaterials, das Naturfasern enthält.

Revendications

1. Séchoir à combustion, en particulier séchoir à combustion à impulsions ou pulsé, pour la déshydratation et/ou la granulation d'une charge d'alimentation humide, en particulier une charge d'alimentation visqueuse telle une charge d'alimentation contenant des fibres naturelles, des sucres et/ou amidons végétaux, comprenant plusieurs, en particulier au moins une première (11a) et une deuxième (11b) chambres de combustion (11a-11d) et une chambre de séchage (10), dans lequel les chambres de combustion (11a-11d) sont connectées à la chambre de séchage (10) ; dans lequel le séchoir à combustion est configuré de manière à ce qu'une oscillation de gaz émergeant dans la chambre de séchage (10) à partir de la première chambre de combustion (11a) est différente, ou peut être contrôlée pour être différente, d'une oscillation de gaz émergeant dans la chambre de séchage (10) à partir de la deuxième chambre de combustion (11b), au moins en ce qui concerne une fréquence d'oscillation, dans lequel le séchoir à combustion est en outre configuré de manière à ce qu'une première fréquence f1 d'oscillation de chambre de combustion, de gaz émergeant dans la chambre de séchage (10) à partir de la première chambre de combustion (11a), et/ou une deuxième fréquence f2 de deuxième chambre de combustion, d'une oscillation de gaz émergeant dans la chambre de séchage (10) à partir de la deuxième chambre de combustion (11b) sont réglées ou contrôlées ou contrôlables à au moins 100 Hz, de préférence à au moins 200 Hz et/ou à pas plus de 1000 Hz, de préférence pas plus de 600 Hz, dans lequel le séchoir à combustion est en outre configuré de manière à ce que des fréquences f1 et f2 de chambre de combustion respectivement de l'oscillation du gaz émergeant dans la chambre de séchage (10) à partir de la première chambre de combustion (11a) et de l'oscillation du gaz émergeant dans la chambre de séchage (10) à partir de la deuxième chambre de combustion (11b) sont adaptées ou contrôlées ou contrôlables de manière à ce qu'une fréquence de battement f3 résultant des fréquences f1 et f2 de chambre de combustion est générée dans la chambre de séchage, dans lequel la fréquence de battement f3 est la valeur absolue

de la différence des fréquences de chambre de combustion f1 et f2 respectivement du gaz oscillant émergeant dans la chambre de séchage (10) à partir de la première chambre de combustion (11a) et du gaz oscillant émergeant dans la chambre de séchage à partir de la deuxième chambre de combustion (11b),

dans lequel la fréquence de battement est au moins de 10 Hz et inférieure à 30 Hz,

dans lequel la fréquence de battement f3 est adaptée ou contrôlée ou contrôlable de manière à correspondre à au moins 0,1 %, de préférence au moins 1 %, de manière davantage préférée, à au moins 2 % de la valeur d'une fréquence plus basse de chambre de combustion et/ou de manière à correspondre à pas plus de 50 %, de préférence pas plus de 20 % de la valeur de la fréquence plus basse de la chambre de combustion,

et dans lequel le séchoir à combustion comprend un moyen de contrôle pour contrôler la première fréquence f1 de chambre de combustion de l'oscillation du gaz émergeant dans la chambre de séchage (10) à partir de la première chambre de combustion (11a) et/ou la deuxième fréquence f2 de chambre de combustion de l'oscillation du gaz émergeant dans la chambre de séchage (10) à partir de la deuxième chambre de combustion (11b) et/ou la fréquence de battement f3 desdites fréquences f1 et f2 et/ou une fréquence moyenne $f4 = (f1 + f2)/2$ desdites fréquences f1 et f2.

2. Séchoir à combustion selon la revendication 1, **caractérisé en ce que** le séchoir à combustion est configuré de manière à ce qu'une oscillation de gaz émergeant dans la chambre de séchage (10) à partir de la première chambre de combustion (11a) est différente, ou peut être contrôlée pour être différente, d'une oscillation de gaz émergeant dans la chambre de séchage (10) à partir de la deuxième chambre de combustion (11b), au moins en ce qui concerne une phase d'oscillation.
3. Séchoir à combustion selon l'une des revendications précédentes, **caractérisé en ce que** plusieurs chambres de combustion (11a-11d) sont disposées sur le même côté de la chambre de séchage (10), par exemple sur un côté du haut ou un côté du bas, et/ou **caractérisé en ce que** plusieurs chambres de combustion (11a-11d) sont disposées sur différents côtés de la chambre de séchage, par exemple au moins une sur le côté du haut et au moins une sur le côté du bas.
4. Séchoir à combustion selon l'une des revendications précédentes, **caractérisé en ce qu'**au moins une chambre de combustion (11a-11d) et la chambre de séchage (10) sont connectées de manière à ce que du gaz de la chambre de combustion (11a-11d)

émerge depuis un côté du bas de la chambre de séchage (10) et/ou qu'au moins une chambre de combustion (11a-11d) et la chambre de séchage (10) sont connectées de manière à ce que du gaz de la chambre de combustion émerge depuis d'un côté du haut de la chambre de séchage (10) et/ou qu'au moins une chambre de combustion (11a-11d) et la chambre de séchage (10) sont connectées de manière à ce que du gaz de la chambre de combustion (11a-11d) émerge depuis un côté de connexion de la chambre de séchage (10) connectant le côté du haut et du bas.

5. Séchoir à combustion selon l'une des revendications précédentes, **caractérisé en ce qu'**au moins une première chambre de combustion (11a) et une deuxième chambre de combustion (11b) sont disposées et connectées avec une chambre de séchage de manière à ce qu'un premier flux de gaz de combustion, qui produit des particules, émergeant dans la chambre de séchage (10) à partir de la première chambre de combustion et un deuxième flux de gaz de combustion, qui produit des particules, émergeant dans la chambre de séchage à partir de la deuxième chambre de combustion, sont dirigés l'un vers l'autre, dans lequel un angle entre les direction d'émergence est au moins de 30°, de préférence au moins de 60°, de manière davantage préférée, au moins de 90° ou au moins sensiblement de 180°.

6. Séchoir à combustion selon l'une des revendications précédentes, **caractérisé par** au moins une conduite d'alimentation en carburant (123), au moins une conduite d'alimentation d'air (126), et au moins un générateur d'air pulsé, dans lequel le générateur d'air pulsé est connecté à la conduite d'alimentation d'air (126) pour générer au moins un premier flux d'air pulsé avec une fréquence d'impulsion f10 entrant dans la chambre de combustion (116), caractérisé en outre de préférence par une deuxième conduite d'alimentation d'air (127) et un deuxième générateur d'air pulsé connecté à la deuxième conduite d'alimentation d'air (127) et configuré pour générer un deuxième flux d'air pulsé avec une fréquence d'impulsion f20 entrant dans la chambre de combustion, dans lequel f20 est de préférence supérieure ou inférieure à f10.

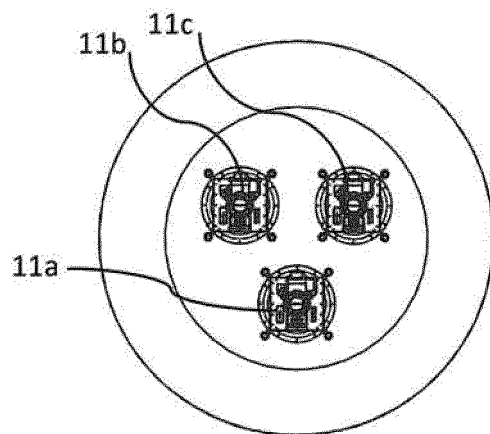
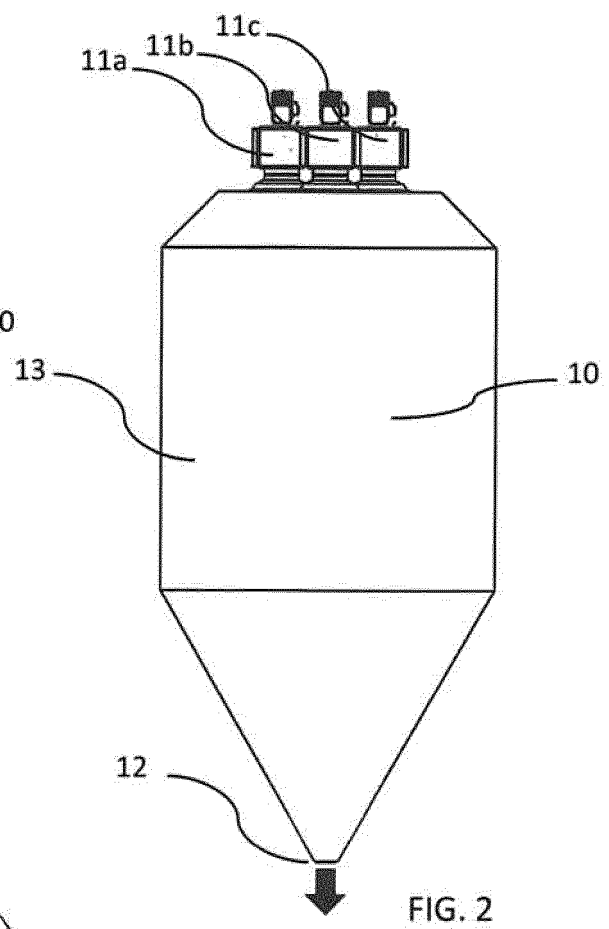
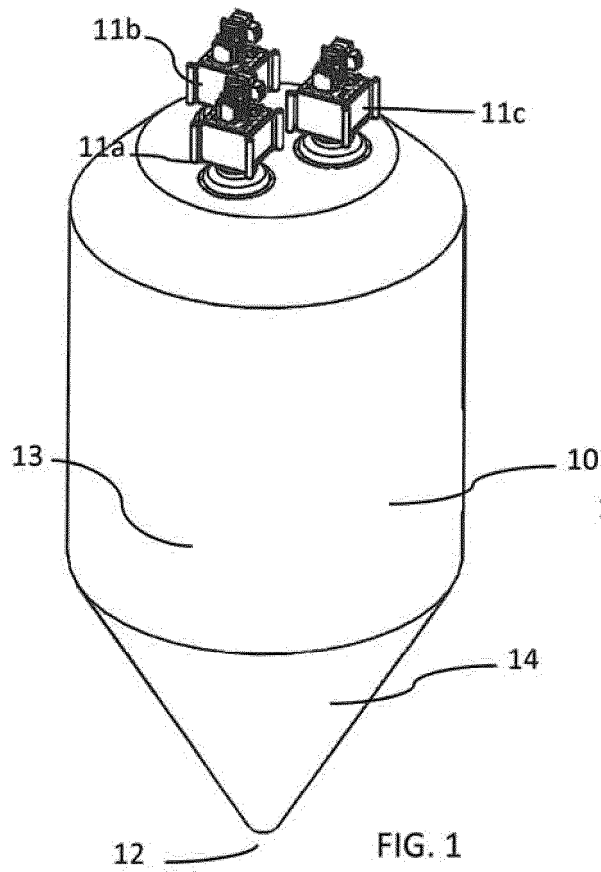
7. Séchoir à combustion selon l'une des revendications précédentes, dans lequel les chambres de combustion (11a-11d) sont connectées à la chambre de séchage (10) de manière à ce que du gaz de la chambre de combustion émerge dans une direction horizontale ou vers le haut.

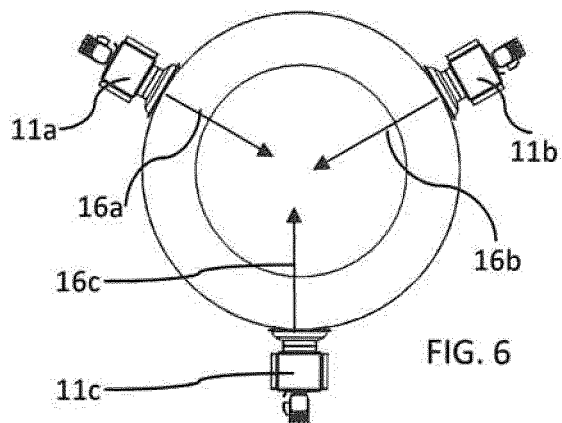
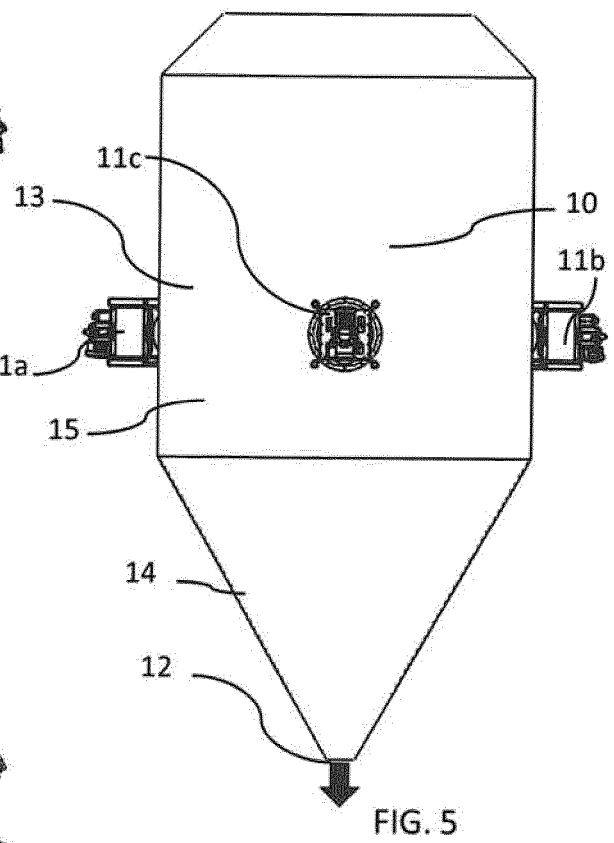
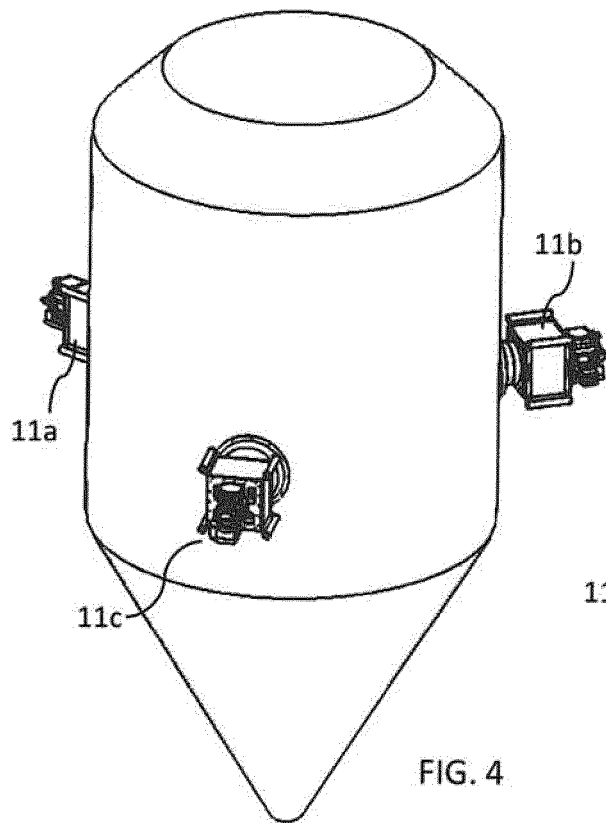
8. Procédé pour la déshydratation et/ou granulation d'une charge d'alimentation humide, en particulier une charge d'alimentation visqueuse telle une char-

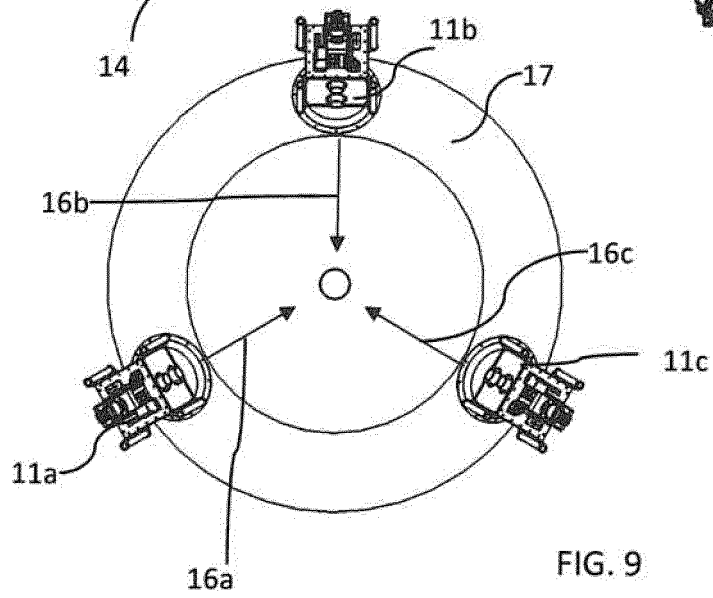
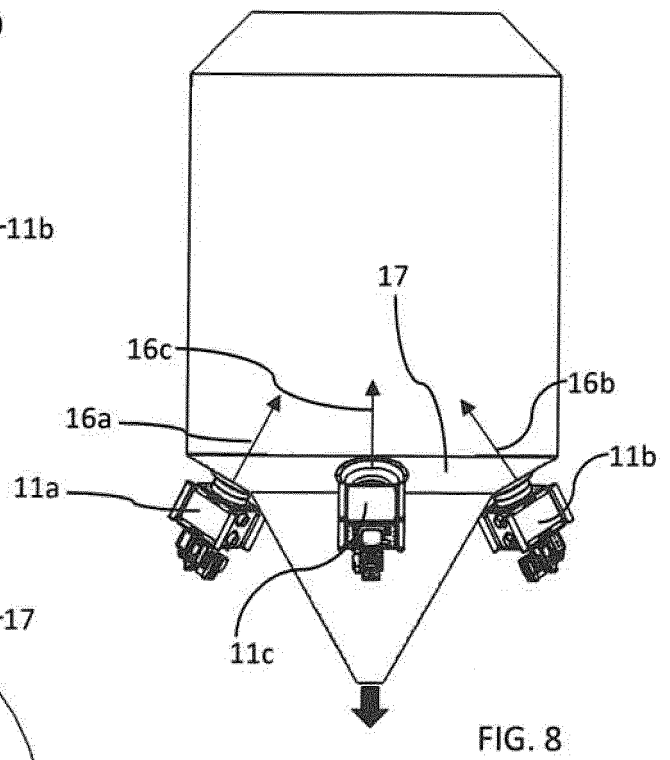
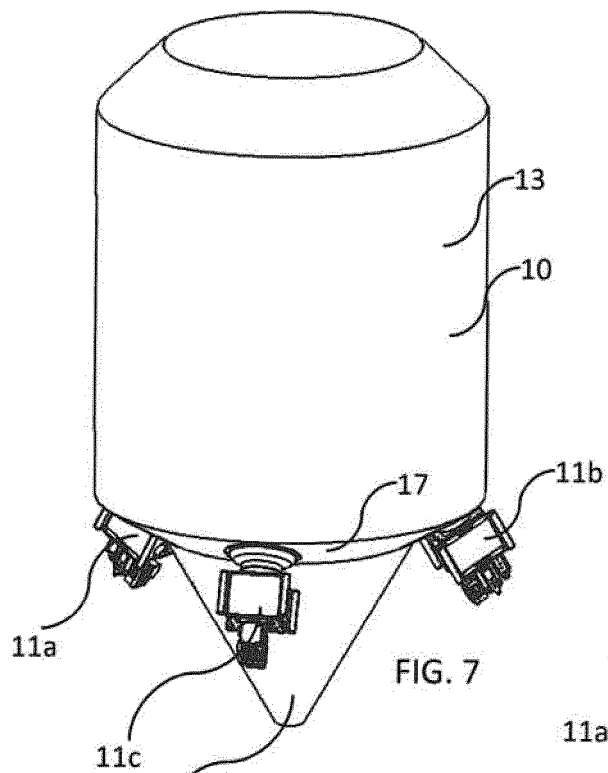
ge d'alimentation contenant des fibres naturelles, des sucres et/ou amidons végétaux, utilisant le séchoir à combustion selon l'une des revendications 1 à 7, comprenant la fourniture d'un premier flux de gaz de combustion, de préférence à partir d'une première chambre de combustion (11a), et d'un deuxième flux de gaz de combustion, de préférence à partir d'une deuxième chambre de combustion (11b), à l'attention de la même chambre de séchage (10), une oscillation du premier flux de gaz de combustion et une oscillation du deuxième flux de gaz de combustion différant l'une de l'autre en ce qui concerne une fréquence.

9. Procédé selon la revendication 8, **caractérisé en ce qu'**une oscillation du premier flux de gaz de combustion et une oscillation du deuxième flux de gaz de combustion diffèrent l'une de l'autre en particulier en ce qui concerne une phase.

10. Utilisation du séchoir à combustion selon l'une des revendications 1 à 7 pour la déshydratation et/ou granulation d'une charge d'alimentation humide, en particulier une charge d'alimentation visqueuse telle une charge d'alimentation contenant des fibres naturelles.







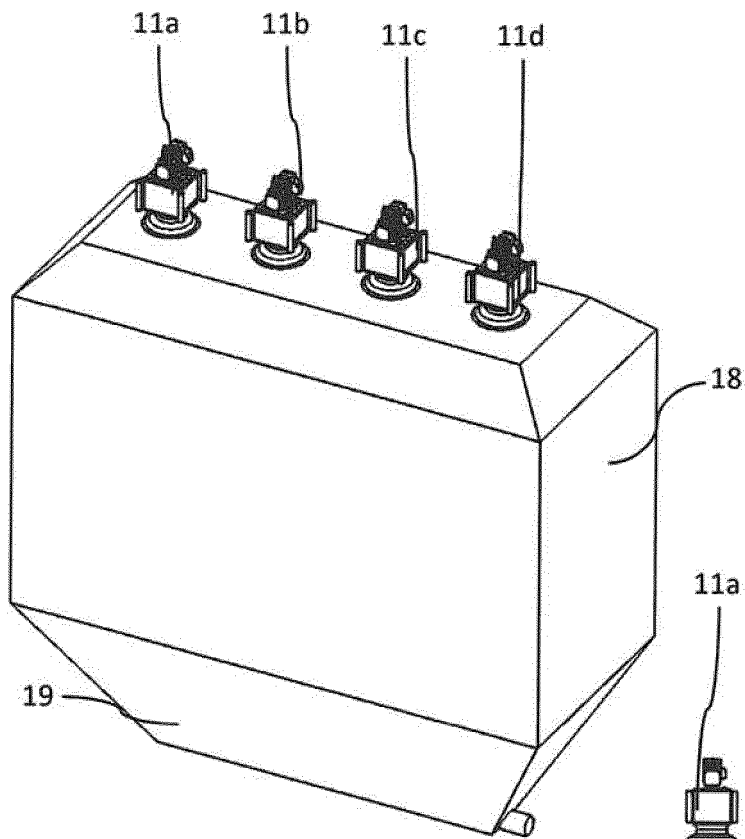


FIG. 10

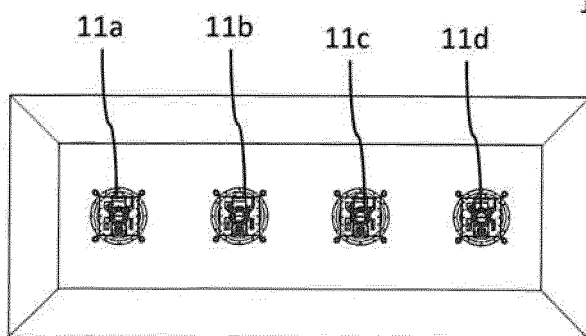


FIG. 12

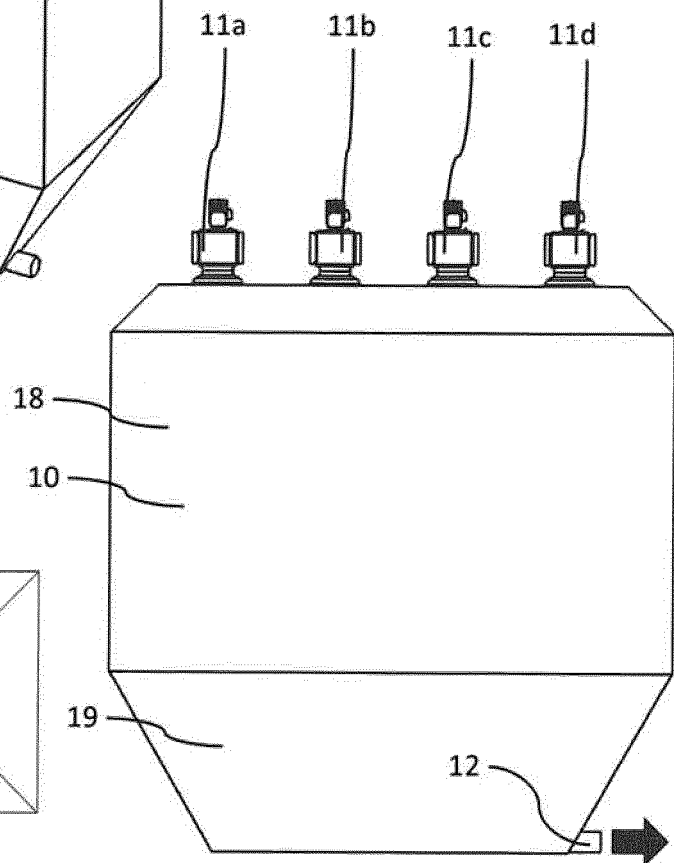


FIG. 11

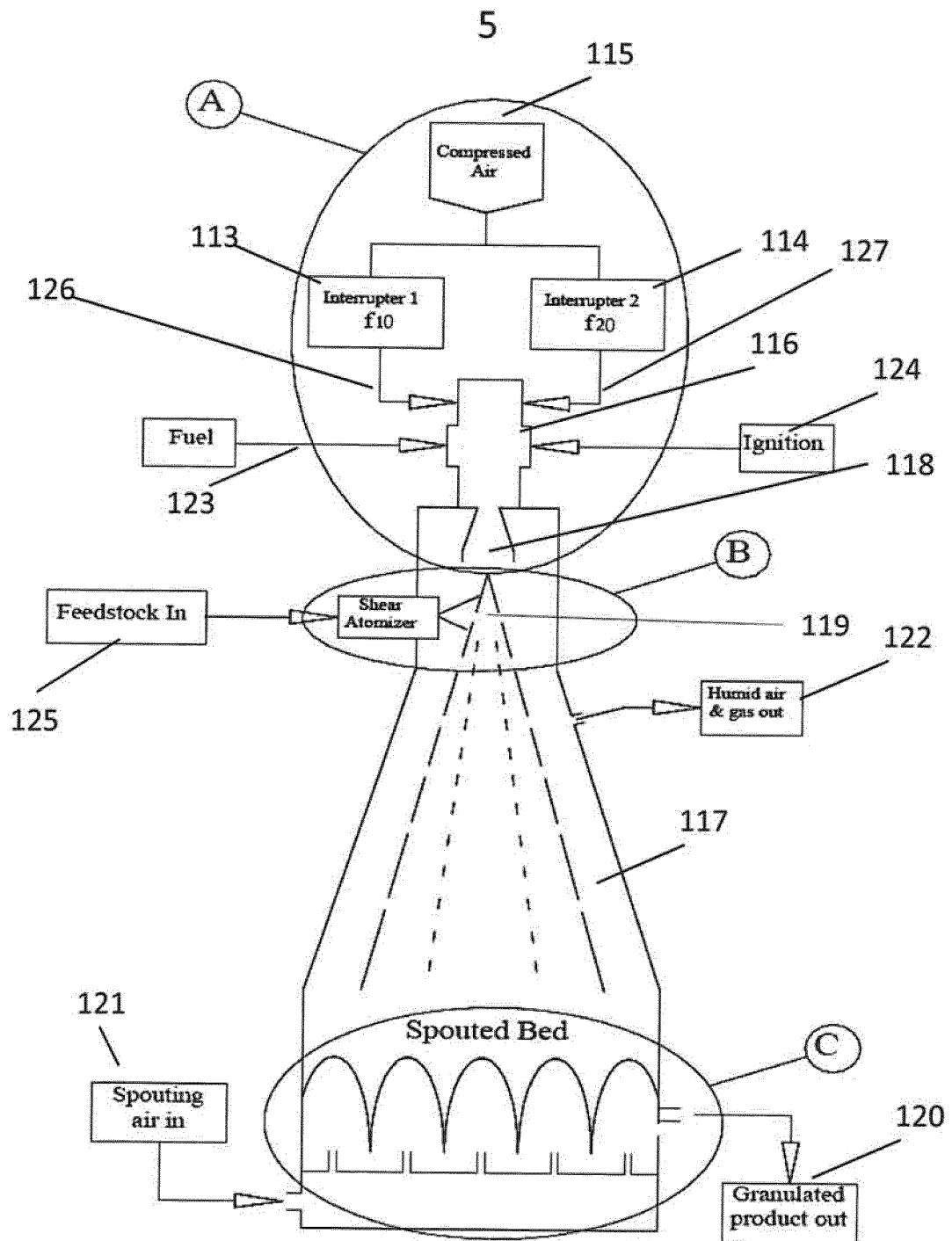


FIG. 13

REFERENCES CITED IN THE DESCRIPTION

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