*System*: a group of interacting, interrelated, or interdependent elements forming a complex whole.

"Ingredient" is used hereinafter in describing the operation of a 3D printer system in the production of a food product according to a recipe, via an additive manufacturing method. However, it will be appreciated by those of skill in the art that the printer system and method of its use can be used to produce non-food products (including, but not limited to such diverse products as soap, wax, and concrete) according to plans, using materials other than the ingredients of food products, and that the use of the terms "recipe" and "ingredient" in the description hereinafter is not intended to limit the invention to the printing of food products, but rather is intended to be non-limiting.

The X-Y-Z 3D printer system 11 of the present invention according to the present invention comprises a capsule changing system (including a capsule repository 25 and components thereof) (shown schematically in Figure 2A), a capsule heating system 500 (shown schematically in Figure 2B), and an extrusion mechanism 511 (shown schematically in Figure 2C), all of which are described hereinafter in greater detail.

Also included in the system 11 as shared components of the capsule changing system, the capsule heating system, and the extrusion mechanism are a processor 17, a tool 23 for extruding material (that is, the ingredient) from the capsules 59 using a telescopic mechanism 511 (described in detail hereinafter), and a controller 21 for controlling the movement of the tool 23 according to computer program instructions stored in a read-write memory (RWM) 19 of the system 11, as described in greater detail hereinafter. Preferably, the system 11 has the processor 17 embedded therein, but the system 11 can be configured to allow a user's external device (for example, a computer or tablet) to communicate with the processor 17, so that the user can control the system 11 via his or her own device.

a. Capsule Changing System

Figure 2A shows the printer system 11 with the elements of capsule changers in block diagram form. The system 11 includes a capsule repository 25 with five capsule-storage stations (slots) 27 (individually designated as 27A, 27B, 27C, 27D, 27E) located adjacent to the printing surface for storing capsules 59 therein, each station 27 being

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Also included in the system 11 as shared components of the capsule changing system, the capsule heating system, and the extrusion mechanism are a processor 17, a tool 23 for extruding material (that is, the ingredient) from the capsules 59 using a telescopic mechanism 511 (described in detail hereinafter), and a controller 21 for controlling the movement of the tool 23 according to computer program instructions stored in a read-write memory (RWM) 19 of the system 11, as described in greater detail hereinafter. Preferably, the system 11 has the processor 17 embedded therein, but the system 11 can be configured to allow a user's external device (for example, a computer or tablet) to communicate with the processor 17, so that the user can control the system 11 via his or her own device.

a. Capsule Changing System

Figure 2A shows the printer system 11 with the elements of capsule changers in block diagram form. The system 11 includes a capsule repository 25 with five capsule-storage stations (slots) 27 (individually designated as 27A, 27B, 27C, 27D, 27E) located adjacent to the printing surface for storing capsules 59 therein, each station 27 being

equipped with sensors 29 for detecting its status (unoccupied or occupied). Each station 27 is equipped also with a capsule holder 53 that embeds various systems therein (as described below) and has the function of holding the capsules 59 (which are individually designated as 59A, 59B, 59C, 59D, and 59E).

Data identifying the capsules 59 is entered automatically from a capsule identification system 41 (described hereinafter) or manually by the end-user through a user interface 15(shown diagrammatically as reference number 15 in Figures 2A - 2C) attached to the system. The entered data is stored in the read write-memory 19 and identifies a station in the repository 25, permitting the selection or fetching of the capsule 59 in that station for use in producing print.

Figures 3A and 3B show the capsule repository 25 with a plurality of stations 27 for storing the capsules 59 (individually designated as 59A, 59B, 59C, 59D, and 59E) and their capsule holders 53 (individually designated as 53A, 53B, 53C, 53D, and 53E) and an exchanger mechanism (described in detail hereinafter) for effecting an exchange of one of the capsule holders 53 between one of the stations 27 and the tool 23. The capsule-storage stations 27(individually designated as 27A, 27B, 27C, 27D and 27E)each contain one capsule holder 53A, 53B, 53C, 53D, and 53E, into which is inserted a respective capsule 59A, 59B, 59C, 59D, and 59E with one of the desired ingredients for carrying out the printing process; the selection of different stations 27 during the printing process, therefore, permits the printing of the design using the different ingredients.

Still referring to Figures 3A and 3B, the exchanger mechanism comprises an engaging mechanism 57 located at each station 27 and an engaging mechanism 49 located in the tool 23, used for effecting an exchange of one of the capsule holders 53 and the capsule 59 inserted therein between one of the stations 27 and the tool 23, and for holding the capsule holder 53 and its capsule 59 once the exchange has taken place. The engaging mechanism 49 of the tool 23 comprises a pair of clips, e.g., tension spring arms 67, 69 provided in the tool 23, which are in an untensioned state when not engaged with a capsule holder 53, and which are in a tensioned state when engaged with a capsule holder 53. The engaging mechanism 57 at each of the stations 27, shown in Figures 6A, 6B, 7A, and 7B, also comprises a pair of clips, e.g., tension spring arms 73, 75, which act upon

equipped with sensors 29 for detecting its status (unoccupied or occupied). Each station 27 is equipped also with a capsule holder 53 that embeds various systems therein (as described below) and has the function of holding the capsules 59 (which are individually designated as 59A, 59B, 59C, 59D, and 59E).

Data identifying the capsules 59 is entered automatically from a capsule identification system 41 (described hereinafter) or manually by the end-user through a user interface 15(shown diagrammatically as reference number 15 in Figures 2A - 2C) attached to the system. The entered data is stored in the read write-memory 19 and identifies a station in the repository 25, permitting the selection or fetching of the capsule 59 in that station for use in producing print.

Figures 3A and 3B show the capsule repository 25 with a plurality of stations 27 for storing the capsules 59 (individually designated as 59A, 59B, 59C, 59D, and 59E) and their capsule holders 53 (individually designated as 53A, 53B, 53C, 53D, and 53E) and an exchanger mechanism (described in detail hereinafter) for effecting an exchange of one of the capsule holders 53 between one of the stations 27 and the tool 23. The capsule-storage stations 27(individually designated as 27A, 27B, 27C, 27D and 27E)each contain one capsule holder 53A, 53B, 53C, 53D, and 53E, into which is inserted a respective capsule 59A, 59B, 59C, 59D, and 59E with one of the desired ingredients for carrying out the printing process; the selection of different stations 27 during the printing process, therefore, permits the printing of the design using the different ingredients.

Still referring to Figures 3A and 3B, the exchanger mechanism comprises an engaging mechanism 57 located at each station 27 and an engaging mechanism 49 located in the tool 23, used for effecting an exchange of one of the capsule holders 53 and the capsule 59 inserted therein between one of the stations 27 and the tool 23, and for holding the capsule holder 53 and its capsule 59 once the exchange has taken place. The engaging mechanism 49 of the tool 23 comprises a pair of clips, e.g., tension spring arms 67, 69 provided in the tool 23, which are in an untensioned state when not engaged with a capsule holder 53, and which are in a tensioned state when engaged with a capsule holder 53. The engaging mechanism 57 at each of the stations 27, shown in Figures 6A, DB, 7A, and 7B, also comprises a pair of clips, e.g., tension spring arms 73, 75, which act upon

into an available (unoccupied) station 27. In depositing a capsule 59 and its capsule holder 53 into an available station 27, the tool 23 is moved from a current position (X0, Y0, Z0) to a position (X4, Y4, Z4) in front of the available station 27. From position (X4, Y4, Z4), the tool 23 is then moved to position (X1, Y1, Z1) in an L-shaped pattern as shown in Figure 5B (the depositing operation being essentially a reverse of the fetching operation). In moving from position (X4, Y4, Z4) to position (X3, Y3, Z4) to deposit the capsule 59 and its capsule holder 53 into the available station 27, for example to deposit the capsule 59C and its capsule holder 53C into the station 27C as shown in Figure 3B, the engaging mechanism 49 of the tool 23 engages the engaging mechanism 57 of the stations 27 and depresses the engaging mechanism 49 of the tool 23 in preparation for deposit (insertion) of the capsule 59C and its capsule holder 53C into the station 27C. Deposit of the capsule 59C and its capsule holder 53C into the station 27C is accomplished by movement of the capsule holder 53C past the spring arms 73, 75. As the capsule holder 53C, with its capsule 59C, travels from position (X4, Y4, Z4) to position (X3, Y3, Z3) within the station 27C, it comes into contact with the spring arms 73,75 and is moved contiguously past them; this causes the spring arms 73, 75 to first recede from the path of the capsule holder 53C then snap back, partially encircling the capsule holder 53C and holding it in place in the station 27C.

From position (X3, Y3, Z3), as shown in Figure 5B, the tool 23 is then moved laterally to position (X2, Y2, Z2). This lateral movement causes the spring arms 67, 69 to move contiguously around and away from the capsule holder 53C, thereby releasing the capsule holder 53C as shown in Figure 7B. From position (X2, Y2, Z2), the tool 23 is then moved to position (X1, Y1, Z1), causing the engaging mechanism 49 of the tool 23 to become disengaged from the engaging mechanism 57 of the station 27. After the capsule 59C has been released, the tool 23 is then moved from position (X1, Y1, Z1) to its initial position (X0, Y0, Z0), thereby completing the deposit operation.

As will be appreciated by those of skill in the art, the exchange process described herein between the station 27C and the tool 23 for the capsule holder 53C and the capsule 59C within is exemplary, a similar exchange process being applicable between all the stations 27 and the tool 23 for all the capsule holders 53 and the capsules 59 therewithin.

into an available (unoccupied) station 27. In depositing a capsule 59 and its capsule holder 53 into an available station 27, the tool 23 is moved from a current position (X0, Y0, Z0) to a position (X4, Y4, Z4) in front of the available station 27. From position (X4, Y4, Z4), the tool 23 is then moved to position (X1, Y1, Z1) in an L-shaped pattern as shown in Figure 5B (the depositing operation being essentially a reverse of the fetching operation). In moving from position (X4, Y4, Z4) to position (X3, Y3, Z4) to deposit the capsule 59 and its capsule holder 53 into the available station 27, for example to deposit the capsule 59C and its capsule holder 53C into the station 27C as shown in Figure 3B, the engaging mechanism 49 of the tool 23 of the tool 23 engages the engaging mechanism 57 of the stations 27 and depresses the engaging mechanism 49 of the tool 23 in preparation for deposit (insertion) of the capsule 59C and its capsule holder 53C into the station 27C. Deposit of the capsule 59C and its capsule holder 53C into the station 27C is accomplished by movement of the capsule holder 53C past the spring arms 73, 75. As the capsule holder 53C, with its capsule 59C, travels from position (X4, Y4, Z4) to position (X3, Y3, Y3) within the station 27C, it comes into contact with the spring arms 73,75 and is moved contiguously past them; this causes the spring arms 73, 75 to first recede from the path of the capsule holder 53C then snap back, partially encircling the capsule holder 53C and holding it in place in the station 29C.

From position (X3, Y3, Z3), as shown in Figure 5B, the tool 23 is then moved laterally to position (X2, Y2, Z2). This lateral movement causes the spring arms 67, 69 to move contiguously around and away from the capsule holder 53C, thereby releasing the capsule holder 53C as shown in Figure 7B. From position (X2, Y2, Z2), the tool 23 is then moved to position (X1, Y1, Z1), causing the engaging mechanism 49 of the tool 23 to become disengaged from the engaging mechanism 57 of the station 27. After the capsule 59C has been released, the tool 23 is then moved from position (X1, Y1, Z1) to its initial position (X0, Y0, Z0), thereby completing the deposit operation.

As will be appreciated by those of skill in the art, the exchange process described herein between the station 27C and the tool 23 for the capsule holder 53C and the capsule 59C within is exemplary, a similar exchange process being applicable between all the stations 27 and the tool 23 for all the capsule holders 53 and the capsules 59 therewithin.

115. At step 115, the position coordinates (X1, Y1, Z1) of the station 27C for commencing the fetching operation are accessed from the controller. A series of four position coordinate values are generated by the processor 17. These position coordinate values for commencing fetching operations with respect to the five stations 27A, 27B, 27C, 27D, 27E shown in Figure 2A, are used in Table 2 below. For example, the coordinates (X1, Y1, Z1) to which the tool 23 must be moved when fetching the capsule holder 53D and its capsule 59D from the station 27D (the fourth station shown in Figure 2A) would be (1200, 500, 400). These coordinates correspond to those of the fourth station (station 27D) used in Table 2.

**Table 2**

Position coordinates for fetching a capsule

| Selected Station | X1 | Y1 | Z1 |
|---|---|---|---|
| 27A | 900 | 500 | 400 |
| 27B | 1000 | 500 | 400 |
| 27C | 1100 | 500 | 400 |
| 27D | 1200 | 500 | 400 |
| 27E | 1300 | 500 | 400 |

Thereafter, as shown in Figures 5A and 8B, in step 117, the value of the X-coordinate is adjusted and the values of the X and Z-coordinates remain unadjusted to produce the position coordinates (X2, Y2, Z2), which are sent to the controller 21 as position coordinates (X2, Y2, Z2). In step 119, the tool 23 is moved to the new position coordinates (X2, Y2, Z2). Afterwards, as shown in step 121, coordinates (X1, Y1, Z1) are sent to the controller 21, thus the tool 23 is moved to these coordinates, thereby fetching the capsule holder 53D and its capsule 59D in the station 27D.

Subsequently, in step 123, the coordinates (X2, Y2, Z2) are sent to the controller 21 and the tool 23 is moved back to the coordinates (X2, Y2, Z2); and in step 125, the coordinates (X3, Y3, Z3) are sent to the controller 21 and the tool 23 is moved back to the coordinates (X3, Y3, Z3).

Following the operation performed at step 125, in step 127, the tool 23 is returned to its original position (X0, Y0, Z0); this original position corresponds to the values of the

115. At step 115, the position coordinates (X1, Y1, Z1) of the station 27C for commencing the fetching operation are accessed from the controller. A series of four position coordinate values are generated by the processor 17. These position coordinate values for commencing fetching operations with respect to the five stations 27A, 27B, 27C, 27D, 27E shown in Figure 2A, are used in Table 3 below. For example, the coordinates (X1, Y1, Z1) to which the tool 23 must be moved when fetching the capsule holder 53D and its capsule 59D from the station 27D (the fourth station shown in Figure 2A) would be (1200, 500, 400). These coordinates correspond to those of the fourth station (station 27D) used in Table 2.

**Table 2**

Position coordinates for fetching a capsule

| Selected Station | X1 | Y1 | Z1 |
|---|---|---|---|
| 27A | 900 | 500 | 400 |
| 27B | 1000 | 500 | 400 |
| 27C | 1100 | 500 | 400 |
| 27D | 1200 | 500 | 400 |
| 27E | 1300 | 500 | 400 |

Thereafter, as shown in Figures 5A and 8B, in step 117, the value of the X-coordinate is adjusted and the values of the X and Z-coordinates remain unadjusted to produce the position coordinates (X2, Y2, Z2), which are sent to the controller 21 as position coordinates (X2, Y2, Z2). In step 119, the tool 23 is moved to the new position coordinates (X2, Y2, Z2). Afterwards, as shown in step 121, coordinates (X1, Y1, Z1) are sent to the controller 21, thus the tool 23 is moved to these coordinates, thereby fetching the capsule holder 53D and its capsule 59D in the station 27D.

Subsequently, in step 123, the coordinates (X2, Y2, Z2) are sent to the controller 21 and the tool 23 is moved back to the coordinates (X2, Y2, Z2); and in step 125, the coordinates (X3, Y3, Z3) are sent to the controller 21 and the tool 23 is moved back to the coordinates (X3, Y3, Z3).

Following the operation performed at step 125, in step 127, the tool 23 is returned to its original position (X0, Y0, Z0); this original position corresponds to the values of the

position coordinates previously stored in the internal memory 19 of the processor 17, as indicated by step 83.

From step 127, exit is made from the routine.

The status of the tool 23 is also checked at the time of commencement of use of the system 11 (i.e., at initialization or "power turn-on" time) by movement of the tool 23 to origin position (X0, Y0, Z0).

b. Capsule Heating System

Automatic capsule heating systems 500 (individually designated 500A, 500B, 500C, 500D, 500E) are provided in the capsule holders 53. The automatic capsule heating system 500 for each capsule holder 53 is shown in Figures 3A, 3B, and 15, and comprises a conducting layer 36 on the interior of the capsule holder 53, an insulating layer 35 on the exterior of the capsule holder 53, a heat sensor 29, and a transducer 31 inserted into the interior of the capsule holder 53, as discussed in greater detail below.

Figure 2B shows the printer system 11 with the elements of the heating system 500 in block diagram form. The UI/UX 15, the processor 17, the controller 21, the tool 23, and the stations 27A, 27B, 27C, 27D and 27E are as described above in connection with Figure 2A. Figures 3B and 3C show the components of the heating systems 500A, 500B, 500C, 500D, and 500E in greater detail, including the respective heat sensors 29A, 29B, 29C, 29D, and 29E for each of the capsule holders 53A, 53B, 53C, 53D, and 53E; and respective transducers(thermal mesh) 31A, 31B, 31C, 31D, and 31E for each of the capsule holders 53A, 53B, 53C, 53D, and 53E. The heat sensor 29 measures the temperature of the capsule holder 53, from which the temperature of the ingredient in the capsule 59 can be inferred. The heat sensor 29 and the transducer (thermal mesh) 31 are both embedded into each capsule holder 53 and connected through the spring pin connector 33 to the station 27 if the capsule 59 of the capsule holder 53 is idle, or to the tool 23 if the capsule 59 of the capsule holder 53 is in use. The spring pin connector 33 is responsible for receiving the power from the controller 21 and transmitting capsule temperature information from the heat sensor 29 to the controller 21.

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From step 127, exit is made from the routine.

The status of the tool 23 is also checked at the time of commencement of use of the system 11 (i.e., at initialization or "power turn-on" time) by movement of the tool 23 to origin position (0,0,0).

b. Capsule Heating System

Automatic capsule heating systems 500 (individually designated 500A, 500B, 500C, 500D, 500E) are provided in the capsule holders 53. The automatic capsule heating system 500 for each capsule holder 53 is shown in Figures 3A, 3B, and 15, and comprises a conducting layer 36 on the interior of the capsule holder 53, an insulating layer 35 on the exterior of the capsule holder 53, a heat sensor 29, and a transducer 31 inserted into the interior of the capsule holder 53, as discussed in greater detail below.

Figure 2B shows the printer system 11 with the elements of the heating system 500 in block diagram form. The UI/UX 15, the processor 17, the controller 21, the tool 23, and the stations 27A, 27B, 27C, 27D and 27E are as described above in connection with Figure 2A. Figures 3B and 3C show the components of the heating systems 500A, 500B, 500C, 500D, and 500E in greater detail, including the respective heat sensors 29A, 29B, 29C, 29D, and 29E for each of the capsule holders 53A, 53B, 53C, 53D, and 53E; and respective transducers (thermal mesh) 31A, 31B, 31C, 31D, and 31E for each of the capsule holders 53A, 53B, 53C, 53D, and 53E. The heat sensor 29 measures the temperature of the capsule holder 53, from which the temperature of the ingredient in the capsule 59 can be inferred. The heat sensor 29 and the transducer (thermal mesh) 31 are both embedded into each capsule holder 53 and connected through the spring pin connector 33 to the station 27 if the capsule 59 of the capsule holder 53 is idle, or to the tool 23 if the capsule 59 of the capsule holder 53 is in use. The spring pin connector 33 is responsible for receiving the power from the controller 21 and transmitting capsule temperature information from the heat sensor 29 to the controller 21.

printing job with capsule 59 has finished, control is transferred to step 203, where the capsule 59 is released and control is transferred back to step 185.

If the result of the test in step 185 is that the capsule is not in use, control is transferred to a station preparation sub-routine at step 205, where a further test is made to determine if the capsule temperature has already reached the desired station temperature according to the information previously fetched in steps 183 and 185. If the result of the test is that the temperature is below the desired station temperature, control is transferred to step 207, where the temperature is increased to the desired level, and then control is transferred to step 209, where the temperature status is updated. If, on the other hand, the capsule temperature was already adequate, control is transferred directly to step 209. Once the station preparation sub-routine is completed, control is transferred to step 211, where a test is performed to determine if the printing job has finished. If the result of this test is that the printing job has not yet finished, control is transferred back to step 185 and the routine for carrying out the heating process continues as previously described. Otherwise, if the printing job is completed, control is transferred to step 213, where the device waits until the capsule cools down to a safe temperature. From step 131, exit is made from the routine for carrying out the heating process.

c. Extrusion Mechanism

Figure 2C shows the printer system 11 with the elements of the extrusion mechanism in block diagram form. The extrusion mechanism comprises an actuator in the form of a telescopic mechanism 511, which is part of the tool 23, in combination with the heat sensors 29 and the transducers 31 previously described. The telescopic mechanism 511 actuates extrusion of the material from the capsule held in the capsule holder.

Figures 12A - 12C show the telescopic mechanism 511 of tool the 23 in greater detail, in three different positions: a rest (retracted) position (Figure 12A), mid-extended position (Figure 12B), and a completely extended position (Figure 12C). When the telescopic mechanism 511 is extended, it pushes a capsule piston 51 at the upper end of the capsule 59, thus producing the extrusion of the ingredient from the lower end of the capsule 59. Extension and retraction of the telescopic mechanism 511 are achieved by way of a motor 61 included in the extrusion mechanism.

printing job with capsule 59 has finished, control is transferred to step 203, where the capsule 59 is released and control is transferred back to step 185.

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c. Extrusion Mechanism

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Figures 12A - 12C show the telescopic mechanism 511 of tool the 23 in greater detail, in three different positions: a rest (retracted) position (Figure 12A), mid-extended position 53 (Figure 12B), and a completely extended position (Figure 12C). When the telescopic mechanism 511 is extended, it pushes a capsule piston 51 at the upper end of the capsule 59, thus producing the extrusion of the ingredient from the lower end of the capsule 59. Extension and retraction of the telescopic mechanism 511 are achieved by way of a motor 61 included in the extrusion mechanism.