Electronic Supplementary Material (ESI) for Digital Discovery.

Autonomous Biomimetic Solid Dispensing using a Dual-Arm Robotic Manipulator

Set-up for the collaborative ABB YuMi Robot IRB 14000:

The YuMi controller was set on automation mode using a 20% speed for safety reasons (all data collected using this 20% speed). After running the program, *scale-client.py* and *target weight client.py* were run at the same time. For this proof of concept, spatulas and hoppers were cleaned manually after dispensing each solid to the various target weights.

Figure S1 demonstrates the Mettler Toledo Quantos XPE206 dosing system equipped with a QH008-BNMW Powder dosing head, as discussed in this paper. All the test settings were entered via the dosing interface; the tolerance settings will be discussed in the next section. At the beginning of each test, an internal adjustment was done to maintain the stability of the internal balance. The procedure of setting up the Quantos was as follows:

Sample numbers were input as 1 /cycle, Sample ID, target weight, and tolerance (**Table S3**) using the Quantos control panel. We then conducted 30 weighing cycles by running the *Quantos-command.py* file. When dispensing was completed, the Quantos head was homed and cleaned.

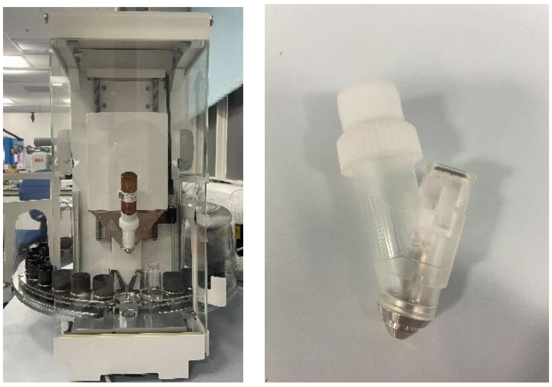

Figure S1. Quantos XPE206 dosing system (left) and QH008-BNMW dosing head (right).

Figure S2 shows the Chemspeed Swing xl Isynth with GDU-Pfd and the layout of the instrument. The dispensing procedure was carried in an Isynth instrument under auto dosing mode. The procedure of setting up Isynth was as follows:

First, we created a macro task with gravimetric transfer using the GDU-Pfd. Then the tool and source was set, as well as the destination, using the auto dispense mode and the GDU-Pfd #1 as the transfer device. High balance stability was chosen under the transfer value options.

The dispensing cartridge with 20 mL capacity is shown in **Figure S2**. For all tests, solids were only filled half in the cartridge to avoid jamming. When solid samples became stuck, the cartridge was cleaned and the solid was reloaded. After dispensing one solid to all target weights, the cartridge was cleaned.

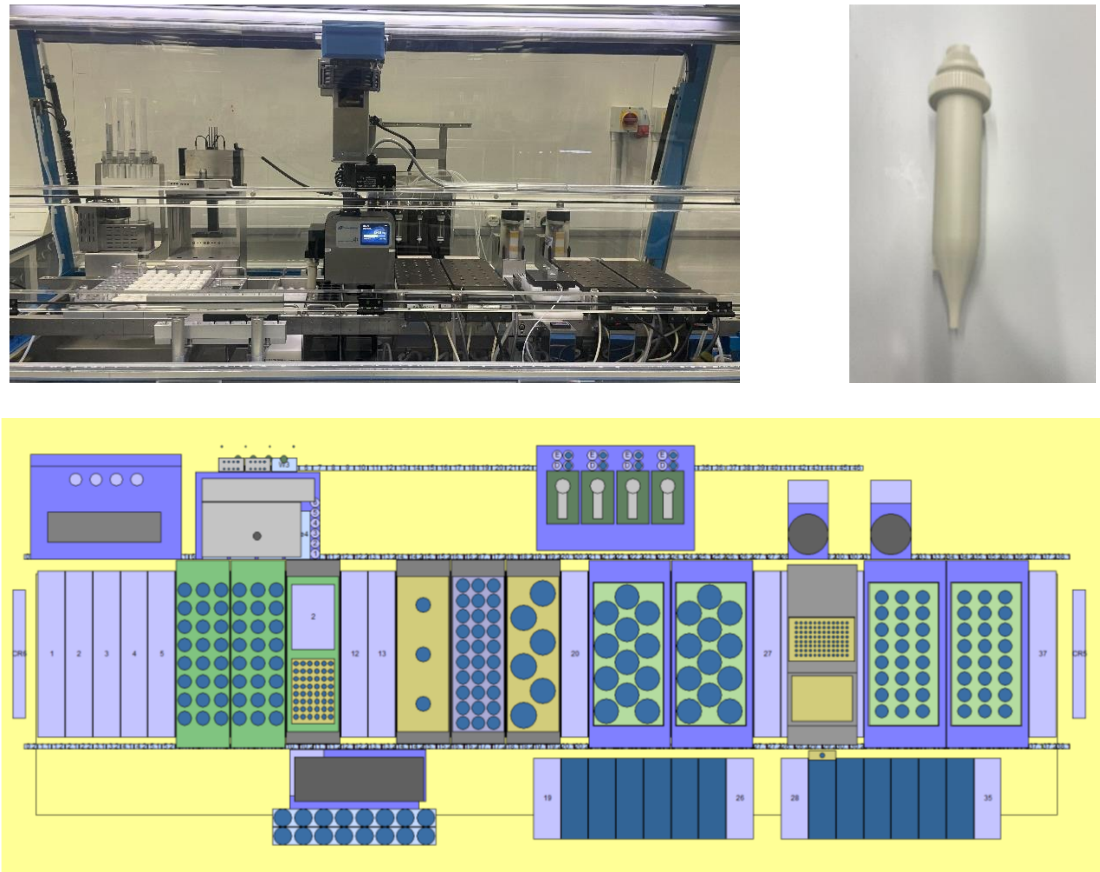

Figure S2. Chemspeed Swing xl Isynth with Gdu-Pdf (up left), 20 mL cartridge (up right), inside layout (right).

Scanning electron microscopy (SEM):

SEM images were collected using a Hitachi S-4800 cold field emission scanning electron microscope. Samples were prepared by depositing the dry powders on 15 S3 mm Hitachi M4 aluminium stubs using an adhesive high-purity carbon tape before coating with a 2 nm layer of gold using an Emitech K550X automated sputter coater. Imaging was conducted at a working voltage of 3 kV and a working distance of 8 mm using a combination of upper and lower secondary electron detectors. The following figures (**Figure S3-1** to **S3-7**) show the SEM images of the dispensed solid samples in this paper.

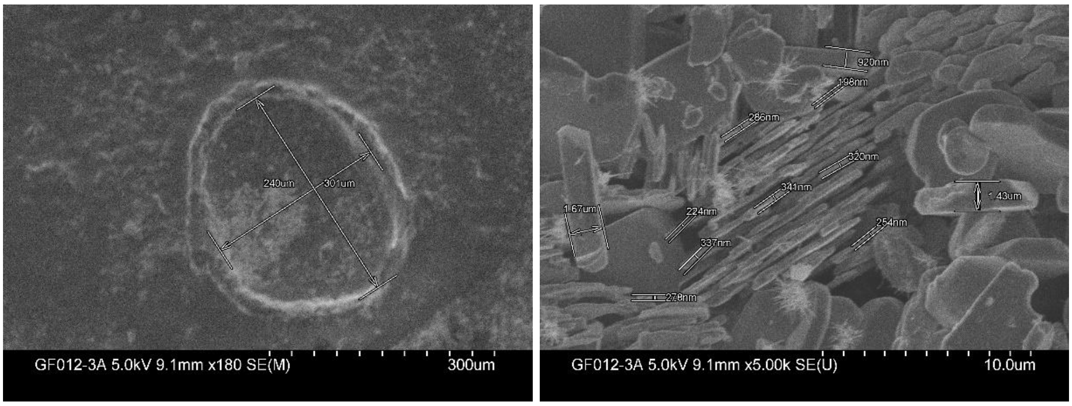

Figure S3-1. SEM images of ammonium acetate (left), aluminium oxide (right).

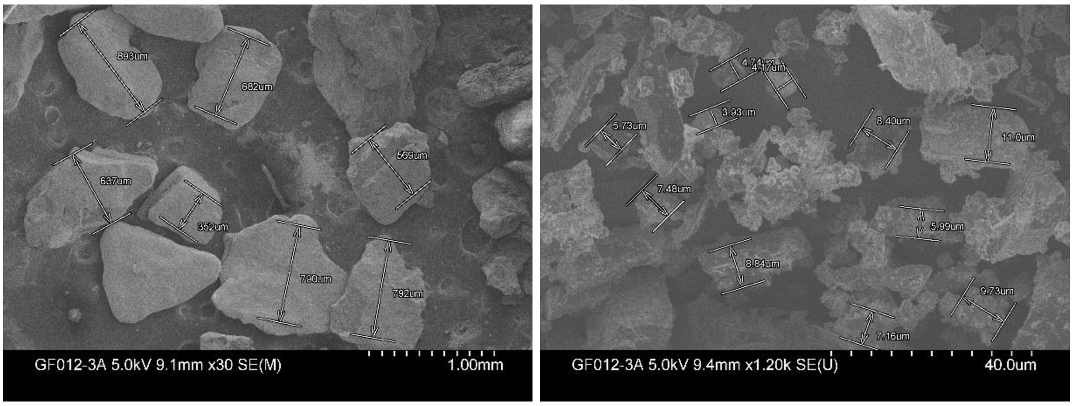

Figure S3-2. SEM images of active carbon (left), calcium carbonate (right).

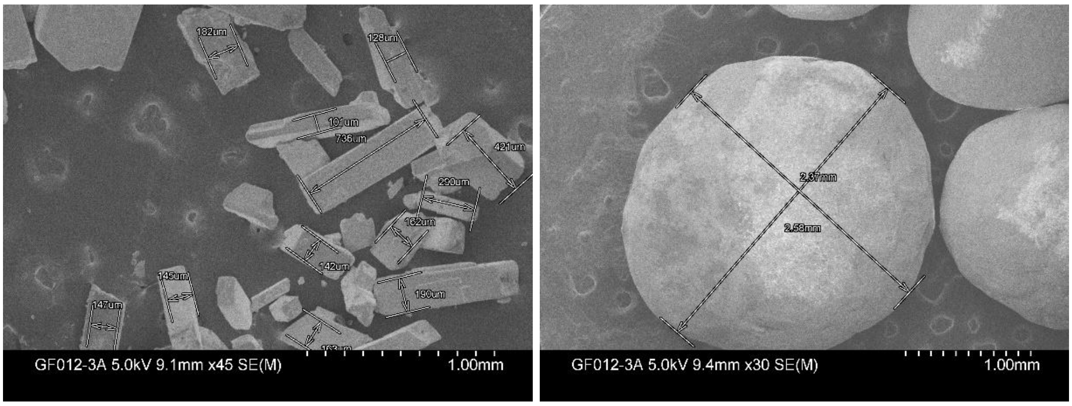

Figure S3-3. SEM images of lithium hydroxide (left), molecular sieve (right).

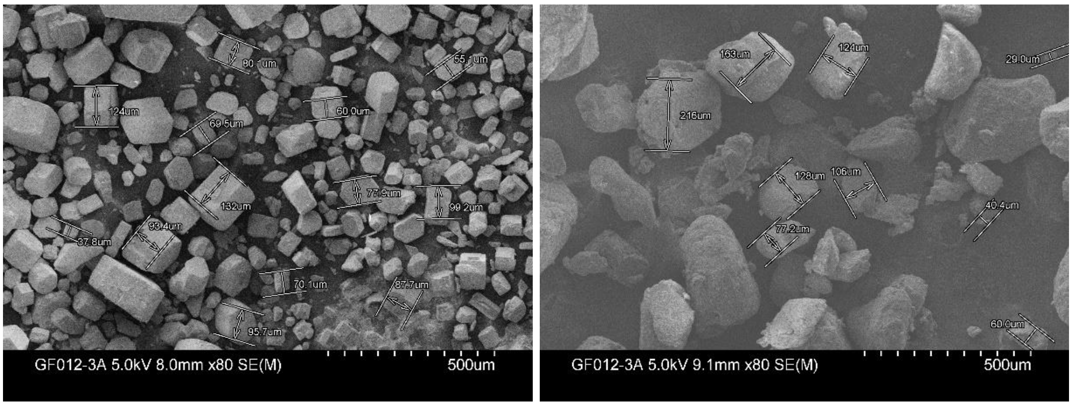

Figure S3-4. SEM images of sodium sulfite (left), sodium nitrite (right).

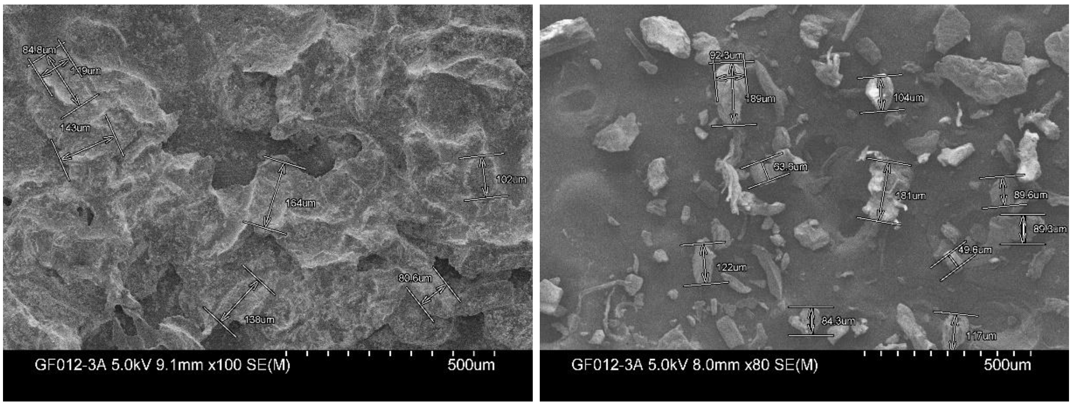

Figure S3-5. SEM images of potassium acetate (left), pectin (right).

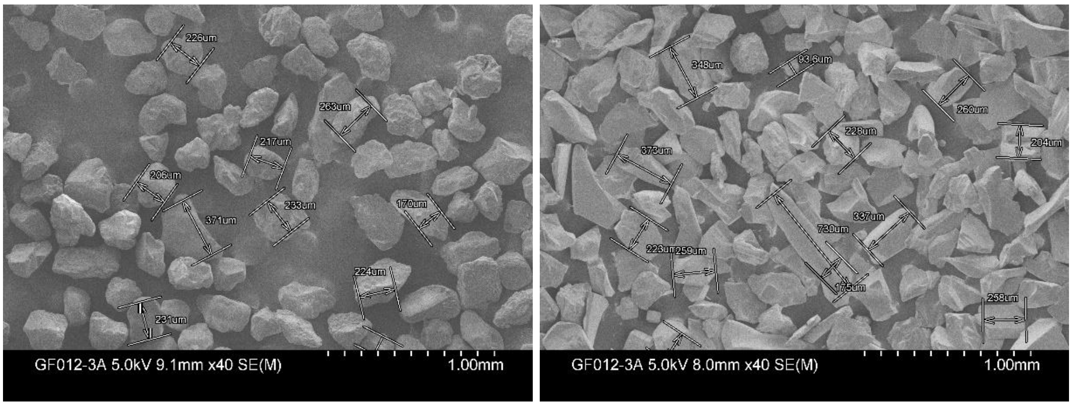

Figure S3-6. SEM images of sand (left), silicon carbon (right).

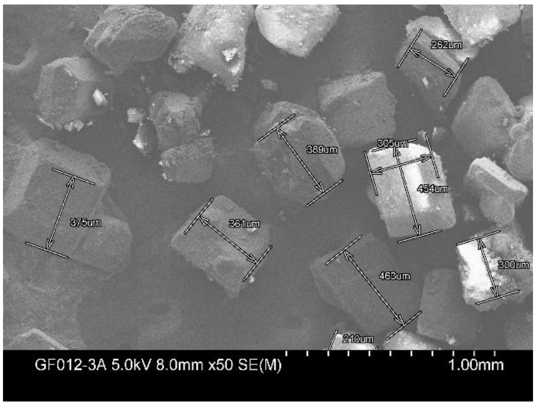

Figure S3-7. SEM image of sugar.

Table S1 lists all the information about the tested solids, including the lot numbers and the supplier names.

Table S1. Information of the solids tested.

Solid	**Lot number**	**Supplier**
Al_2O_3	SZB82970	Sigma-Aldrich
Active carbon	SLBC9632V	Sigma-Aldrich
Pectin	B075X4FHGG	Intralabs
Molecular Sieve	STBD5674V	Sigma-Aldrich
Granulated sugar	5010067337501	Tesco
$NaNO_2$	MKCH7290	Sigma-Aldrich
Na_2SO_3	A0381725	Acros organics
$LiOH.H_2O$	BCBG5911V	Sigma-Aldrich
Sand	2195487	Fisher Chemical
SiC	CDUK02	Generic (Amazon)
$CaCO_3$	MKCP8121	Sigma-Aldrich
CH_3COOK	MKBL2084V	Sigma-Aldrich
$NH_4CH_3CO_2$	BCCD6642	Sigma-Aldrich

Table S2 shows the weight change of testing solids after being exposed to air for a specified number of days; the water absorption rate of each material was calculated based on the 14 days solid weight data. The first column represents the nascent weight of the material when freshly dried, and the following three columns indicate the weight of the solid being exposed to air for 3 days, 5 days, and 14 days, respectively.

Table S3 indicates the tolerance setting on three dispensing platforms (unit: mg). The tolerance has been set as 2 mg for most of the solids; whilet 20 mg was set for molecular sieves since the average weight of each individual particle is between 5–10 mg.

Table S2. Material weight after exposing to air for various times.

	W (dried g)	W (3 days)	W (5 days)	W (14 days)	Water %
Molecular sieve	13.278	13.373	13.376	13.402	5.2
SiC	12.997	12.998	12.996	13	0.5
Sand	13.1	13.104	13.104	13.104	0.2
$CaCO_3$	12.928	12.929	12.929	12.929	0.0
Active carbon	13.107	13.186	13.192	13.241	6.1
Al_2O_3	12.995	12.997	12.996	12.996	0.0
$NaNO_2$	12.8	12.808	12.806	12.819	1.0
Granulated sugar	12.839	12.845	12.843	12.849	0.5
Na_2SO_3	12.913	12.914	12.913	12.915	0.1
Pectin	12.649	12.749	12.755	12.792	8.3
CH_3COOK	13.145	13.296	13.425	13.896	33.4
$NH_4CH_3CO_2$	11.811	12.842	11.852	12.056	26.6
$LiOH.H_2O$	12.191	12.309	12.364	12.769	44.8

Table S3. Tolerance setting of different dispensing platforms (mg).

Solid	Dual-arm robot	Quantos	Chemspeed
Al_2O_3	2	2	2
Active charcoal	2	2	2
Pectin	2	2	2
Molecular Sieve	20	20	20
Sugar	2	2	2
$NaNO_2$	2	2	2
Na_2SO_3	2	2	2
$LiOH.H_2O$	2	2	2
Sand	2	2	2
SiC	2	2	2
$CaCO_3$	2	2	2
CH_3COOK	2	2	2
$NH_4CH_3CO_2$	2	2	2

Table S5 and **Table S6** list the rule base for FLC1 and FLC 2 separately.

Table S5. FLC1 table rule base.

Difference /Particle size level	S	L
S	S	S
M	L	M
L	L	L

Table S6. FLC2 table rule base.

Difference /Particle size level	S	L
VS	S	VS
S	S	S
M	L	M
L	VL	L
VL	VL	L