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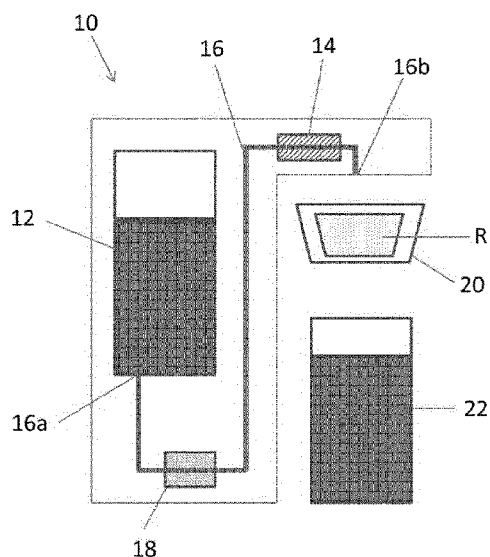
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(54) **Title:** REMOVAL OF INORGANIC ARSENIC FROM A PARTICULATE FOOD

Figure 1



(57) **Abstract:** The present invention provides an apparatus for cooking a particulate food, the apparatus comprising a condenser for condensing the vaporised water, and a retainer for holding the particulate food, wherein the retainer is arranged to receive the condensed water and to allow the condensed water to percolate through and exit the particulate food. The invention also provides a method of cooking a particulate food to remove at least some arsenic from the particulate food.

Removal of inorganic arsenic from a particulate food

Field of the Invention

- 5 This invention relates to an apparatus for cooking a particulate food, and a method of cooking the particulate food to remove at least some inorganic arsenic from the particulate food.

Background of the Invention

- Inorganic arsenic (As_i) is a class-one, non-threshold carcinogen whose primary input into global diets
10 is through rice. Levels of As_i in rice are of such concern, along with the fact that there is a high gut bioavailability of rice As_i , that even low rice consuming regions of the world such as the European Union (EU) and the United States of America (USA), with a median consumption of circa. 20g/d, have recognized the need to set regulations for As_i content of foods as currently they have no standards. As_i exposure from rice is exacerbated in the traditional high rice consuming countries of
15 the world in S.E. Asia, where consumption rates typically vary from 150-500 g/d per person. Furthermore, the most susceptible sub-populations with respect to As_i in the diet are children < 4.5 y old as the risk of As_i exposures as children eat ~3-times as much rice as adults on a body weight basis. Young children are also known to be more susceptible to As_i yet they are more reliant on rice based foods, particularly at weaning as rice is a preferred cereal at this stage due to being gluten
20 free and having good textural properties, with surveys of products such as baby rice finding them particularly elevated in As_i .

- Rice grain is elevated ~10-fold in As_i compared to other crops as it is the only major crop that is grown anaerobically and it is the arsenic (As) biogeochemical cycle under anaerobic conditions that
25 is responsible for rice grain being high in As_i as rice itself does not differ much itself in its assimilation, metabolism and transport of As as compared to other cereal crops. Under aerobic conditions, i.e. the condition under which the vast majority of arable crops are cultivated naturally, as well as any anthropogenic further elevation, As_i is mainly locked in iron oxyhydroxide ($Fe(III)OOH$) minerals as arsenate and is poorly available to plants, with arsenate assimilated by roots as it is an
30 phosphate analogue. Under anaerobic conditions insoluble Fe^{3+} is reduced to soluble Fe^{2+} and arsenate (As^{5+}) to uncharged and more mobile arsenite (As^{3+}), with plants actively assimilating arsenite as it is a silicic acid analogue and rice has a high demand for silicic acid. Even at low and natural levels of As in soils rice plants are effective at assimilating As_i as there is a very steep dose dependent soil-grain uptake up to 2 mg/kg As in soil, and at higher soil concentrations of As
35 assimilation into grain becomes saturated. Globally, soil As is ~5 mg/kg over 2-times the soil concentration at which rice grain As starts to saturate.

- A number of solutions have been tried to reduce grain As_i , namely breeding, field management and processing. Association mapping has shown that As in rice grain is under genetic control but there
40 are multiple loci responsible, all with only a small contribution to As grain burdens, with strong genotype*environment interactions, suggesting that the breeding option needs further development.

If rice is grown aerobically, which it does readily, often with little effect on yield, grain As can be reduced ~10-fold but unfortunately grain Cd is raised by an order of magnitude, and grain Cd is also highly problematic in rice grain. This leaves processing as the best strategy for grain As_i mitigation. Bran is much more enriched in As_i compared to polished (white) rice, though the milled bran component is only ~10% of wholegrain biomass. Wholegrain rice is elevated in As_i compared to polished rice, but the levels of As_i within polished rice are still highly problematic. The way that rice is cooked has shown to have an effect on As_i content of cooked grain. The common way to cook rice is to cook it in a volume of water that will result in all the water being absorbed or evaporated and this does not cause loss of As_i on cooking and, indeed, where the cooking water itself is elevated in As_i, such as in large tracts of Bangladesh, cooking further elevates the arsenic content of the cooked product. Traditional S.E. Asian methods of rice cooking involved extensive rinsing of the uncooked grain followed by cooking the rice in a large excess of water and discarding that water on cessation of cooking and this was found to reduce As_i content of food by up to ~30% when As_i-free water was used. Steaming is one traditional cooking approach where rice is not directly exposed to cooking water, but steaming can only remove up to about 10% of As_i, not as effective as large traditional S.E. Asian boiling water techniques.

Rice cookers are known in the art. US 2007/0190221 A1 discloses a method and apparatuses for healthy rice cooking and removing starch in rice. The disclosed rice cooker includes: an inner pot, an outer case with control buttons, a power input terminal, a thermostat component, a control circuit, a rice cooker lid and a heater plate. The inner pot is placed inside the outer case, and the heating plate, the thermostat and the control circuit are placed at the bottom of the inner pot. A starch removing device is placed between the bottom of the inner pot and the outer case, and the starch removing device comprises: a heating plate, a power input terminal, a thermostat component, a control circuit disposed at the bottom, a medium case inside the outer case, a water storage trough at the exterior of the medium case, a water drainage trough between the medium case and the outer case, and an evaporating tube at the bottom of the water storage trough. The ends of the evaporating tube are connected with the water storage trough and the inner pot through a channel, whereas, the water drainage trough is connected with a valve and the bottom of the inner pot through channels. Water is evaporated to steam which condenses and soaks the rice in the inner pot. Once the condensed water been passed through the rice, it is collected in the water drainage trough and then discarded.

The present invention has been devised with a view to mitigating the limitations of conventional methods and to optimise the removal of As_i from a particulate food such as, but not limited to, rice.

Summary of the Invention

Accordingly, the present invention provides an apparatus for cooking a particulate food, the apparatus comprising:

- a condenser for condensing vaporised water, and
- a retainer for holding the particulate food,

wherein the retainer is arranged to receive the condensed water and to allow the condensed water to percolate through and exit the retainer.

Optionally, the apparatus further comprises a heater for vaporising water.

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Further optionally, the apparatus comprises a water source in fluid communication with the heater.

Thus, the apparatus of the invention is configured to cook a particulate food, such as rice, by percolating condensed water through the particulate food. By heating the water to create vaporised
10 water (or steam), and using the condensed water to cook the rice, any contaminants in the water are prevented from contacting the particulate food during the cooking process. Furthermore, percolation of the condensed water through the particulate food removes arsenic from the particulate food. Sustained or repeated percolation of the condensed water through the particulate food results in the improved removal of arsenic from the particulate food compared to conventional cooking methods.

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Optionally, the apparatus is connectable, optionally reversibly connectable, to a water source. Such a water source may be, for example, a tap or mains water supply. Optionally, the apparatus comprises a reservoir. Optionally, the reservoir is configured to receive water from a water source. Optionally, the reservoir comprises an inlet to receive water from a water source. Optionally, the
20 reservoir is connectable, optionally reversibly connectable, to a water source. Optionally, or additionally, the reservoir is configured to receive water from a water source and to hold the water in the apparatus. Optionally, the reservoir is configured to hold between about 1-10 litres of water, optionally between about 2-6 litres of water.

25 Optionally, the heater may be heated by an external heat source. Such an external heat source may be, for example, a stove or a fire. Optionally, the heater comprises an electrical heating element which may be heated by passing electricity through the heating element. Optionally, the heating element is arranged to impart heat to the water in the reservoir. Optionally, the heating element is located at or adjacent the reservoir. Optionally, the reservoir comprises a reservoir housing in which
30 the heating element is integrally formed. Optionally, the apparatus further comprises a channel to allow passage of water and/or steam between the reservoir and the condenser, the channel terminating in a proximal opening adjacent the water source and a distal opening adjacent the condenser. Optionally, the heater is arranged to transfer heat to the water in the channel. Optionally, the channel is a pipe, optionally a water-impermeable pipe.

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Alternatively, or additionally, the heater comprises a heating element located inside the reservoir. Optionally, the heating element is an electrical heating element which may be heated by passing electricity through the heating element and which can impart heat to the water in the reservoir.

40 Optionally, the condenser comprises a condensing surface with which the vaporised water can directly or indirectly contact. Direct or indirect contact with the condensing surface can cause the

some or all of the vaporised water to condense. The condensed water may typically have a temperature of about 100° C, optionally between about 90-100° C. Optionally, the condensing surface is passively cooled by exposure to ambient temperature. Such ambient temperature may correspond to the temperature of the room or area in which the apparatus is located, in use or prior to use. Optionally, the condensing surface is actively cooled by exposure to a cooler. Optionally, the cooler comprises a fan-assisted cooler. Alternatively, the cooler comprises a thermoelectric cooler.

Optionally, the apparatus comprises a distributor to distribute the condensed water to the particulate food in the retainer, for example, a basket. Optionally, the distributor comprises an opening at or adjacent the distal opening of the channel. Optionally, the distributor comprises a spout or nozzle at or adjacent the distal opening of the channel. Optionally, the spout or nozzle comprises one or more apertures through which the condensed water can pass. Optionally, or additionally, the distributor comprises a plate located between the condenser and the retainer, wherein the plate comprises one or more apertures through which the condensed water can pass. The spout, nozzle and/or plate function to distribute the condensed water through the particulate food, thus helping to ensure even and complete cooking of the particulate food, and/or optimise removal of arsenic from the particulate food.

Optionally, the retainer is configured to retain the particulate food substantially beneath the condenser and/or distributor. In this configuration, the condensed water can pass into the particulate food. Optionally, the condensed water can pass into the particulate food under the influence of gravity. Optionally, the condensed water can pass into the particulate food under pressure, said pressure being produced by the steam generated by the apparatus, or by mechanical means such as a pump.

Optionally, the retainer comprises one or more clamps or supports to retain the particulate food in the apparatus. Optionally, the one or more clamps or supports are suitable to retain particulate food contained in bags or other containers. Such bags or other containers may contain one or more apertures to allow the condensed water to percolate through and exit the particulate food.

Optionally, the retainer comprises a basket. Optionally, the basket is removable from the apparatus. Optionally, the basket comprises one or more apertures through which the condensed water can exit the basket. Optionally, the one or more apertures are configured to inhibit or prevent entry of vaporised water into the basket. Optionally, or additionally, the apparatus further comprises a shield having one or more apertures through which the condensed water can exit from the basket, but which are configured to inhibit or prevent entry of vaporised water into the basket, such as can be found in a pot-percolator. Optionally, the shield is disposed between the reservoir and the basket.

Optionally, the retainer is configured to hold between about 0.1-2 kg of particulate food, optionally between about 0.5-1 kg of particulate food.

Optionally, the apparatus comprises a trap to collect condensed water that has passed through the particulate food, the basket and/or the shield. Optionally, the trap is located substantially beneath the particulate food, the basket and/or the shield. Optionally, the trap is in fluid communication with the reservoir. In this arrangement, the condensed water is allowed to return to the reservoir from
5 where it may be re-vaporised. Optionally, the trap and the reservoir form a single vessel. In this arrangement, vaporised water may be generated in the vessel or channel, as described above, passed through the channel to the condenser from which condensed water is passed to the particulate food, optionally via the distributor, wherein the condensed water percolates through and exits the particulate food. The condensed water is then returned to the vessel from where it may be
10 re-vaporised.

In a further aspect, the method of cooking a particulate food to remove at least some arsenic from the particulate food, the method comprising:

- (i) condensing vaporised water; and
- 15 (ii) percolating the condensed water through the particulate food until the particulate food is cooked and/or until a pre-determined quantity of arsenic has been removed from the particulate food.

Optionally, the method of cooking particulate food is performed using the apparatus of the invention.

20 Optionally, the method further comprises vaporising water to form vaporised water (or steam).

Optionally, the vaporising step comprises using a heater as described above to vaporise water to form vaporised water.

25 Optionally, the condensing step comprises using a condenser as described above to condense the vaporised water.

Optionally, in percolating step, the condensed water is percolated through the particulate food for 1-60 minutes, optionally 1-45 minutes, optionally 5-30 minutes, further optionally, 10-20 minutes. It will
30 be appreciated that the appropriate time for which the condensed water to percolate through the particulate food will depend largely in the type of particulate food to be cooked and/or the amount of arsenic to be removed from the particulate food.

Optionally, the pre-determined quantity of arsenic to be removed from the particulate food is at least
35 30%, optionally at least 50%, optionally at least 60%, optionally at least 70%, optionally at least 80%, optionally at least 90%, optionally at least 95%, or optionally substantially all, of the arsenic present in the particulate food prior to the cooking the particulate food according to the method of the invention.

40 Optionally, the method further comprises collecting the condensed water that has percolated through the particulate food, and discarding the condensed water, or re-vaporising the condensed water.

Brief Description of the Drawings

Embodiments of the present invention will now be described, by way of example, with reference to
5 the accompanying drawings, in which:

FIG 1 is a side view of an embodiment of an apparatus of the invention.

FIG 2a is a side view of a further embodiment of an apparatus of the invention.

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FIG 2b is a side view of the embodiment of FIG 2a in which the reservoir and trap are in fluid communication.

FIG 3 is a side view of a further embodiment of an apparatus of the invention.

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FIG 4 is a side view of a further embodiment of an apparatus of the invention.

FIG 5 depicts the loss of DMA, As_i and total As on cooking 10g (filled bars) or 2g (hashed bars) of rice by Soxhlet for different numbers of reflux cycles for USA white rice purchased in the UK
20 compared to uncooked (white bars). Each bar is the average of 3 replicates, whiskers represent the standard error of the mean.

FIG 6 depicts the loss of total elements on cooking 10g of rice by Soxhlet for different numbers of reflux cycles for USA white rice purchased in the UK. Each point is the average of 3 replicates, bars
25 are standard errors on the mean. Elements measured by ICP-MS, with CRM recovery in parenthesis, are Mg (91%), Mn (94%), Na (124%), P (77%), Fe (78%), Co (134%), As (74%), Rb (96%), Mo (93%) & Cd (139%). Elements measured by XRF, with CRM recovery in parenthesis, are K (84%) and Ca (79%).

FIG 7 represent the loss of DMA (open bars), As_i (diagonal hashed bars) and total As (cross hatched bars) on cooking 10g of rice by Soxhlet for different numbers of reflux cycles for USA white rice
30 purchased in the UK comparing uncooked (white bars), cooked top 3 cm of Soxhlet thimble and cooked bottom 3 cm of Soxhlet thimble. Each bar is the average of 3 replicates, whiskers represent the standard error of the mean.

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FIG 8 depicts boxplot with lines representing median, 25th & 75th percentiles, whiskers 5th and 95th percentiles and dots outliers for DMA, As_i , and total As concentrations in 20 different rice samples in either uncooked rice, 10g cooking of rice at 2 and 4 Soxhlet refluxes, and 2g cooking of rice at 3 Soxhlet refluxes.

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FIG 9 depicts relationship between 2g of rice cooking at 3 Soxhlet refluxes and uncooked rice for DMA, Asi, and total As concentrations in 40 different rice samples. Filled symbols are wholegrain, unfilled are polished rice. Different symbols represent different countries: plus, Australia; cross, Egypt, triangle, EU; star, France; circle, Italy; inverted triangle, Japan; square with cross, Lebanon; 5 quartered square, Pakistan; square, Spain; diamond, Thailand; hexagon with cross, Turkey; hexagon, USA. The solid line shows the 1:1 relationship between cooked and uncooked rice, and the dashed line shows the correlation between these 2 parameters.

Description of Preferred Embodiments

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The present invention provides an apparatus for cooking a particulate food such as rice. For the purposes of this description, the particulate food will be referred to as rice. However, it will be appreciated that the particulate food which may be cooked using the apparatus of the invention, or according to the method of the invention, may be any suitable particulate food such as non- 15 dehusked rice (rough rice), wholemeal rice, grains, cereals, pulses, and the like. The apparatus of the invention is configured such that the rice is cooked by percolating condensed water through the rice in order to cook the rice and/or to remove at least some arsenic from the rice. It will be understood that as well as arsenic, the apparatus of the invention is suitable for removing other contaminants from rice or other particulate food. Such contaminants include rodent faeces, bacterial 20 toxins, mineral oil (batching oil), and other metal contaminants. Thus, the apparatus of the invention comprises a heater for vaporising water to steam, a condenser for condensing the vaporised water, and a retainer for holding the rice. The retainer is arranged to receive the condensed water and to allow the condensed water to percolate through and exit the rice. The invention also provides a method of cooking rice to remove at least some arsenic from the rice. The method is also suitable 25 for removing other contaminants such as those described above.

With reference to Figure 1, an embodiment of the apparatus of the invention is shown in which the apparatus 10 comprises a reservoir 12 in fluid communication with a condenser 14 via a channel 16. The reservoir 12 is arranged to receive and hold water and to supply water to a heater 18. In 30 operation, the water from the reservoir 12 is heated by the heater 18 so as to vaporise at least some of the water to vaporised water (or steam). The vaporised water then passes to the condenser 14 via channel 16 which has a proximal opening 16a adjacent the reservoir 12 and a distal opening 16b adjacent the condenser 14. The condenser 14 may comprise a condensing surface which is cold relative to the vaporised water and therefore causes at least some of the vaporised water to 35 condense. The vaporised water may condense as a result of directly contacting the condensing surface, or as a result of being cooled by the ambient temperature in the channel 16, which temperature may be controlled by the condenser 14. The condensed water, which is still close to the boiling point of water (i.e. about 100° C), then passes from the distal opening of the channel 16b to the rice R which may be held in a basket 20. The condensed water percolates through the rice R 40 thereby cooking the rice R and leaching arsenic from the R. The condensed water containing some of the arsenic from the rice then exits the rice R and the basket 20 through at least one aperture (not

shown) in the basket B. The condensed water may then be collected in a trap 22 from which it may be discarded or returned to the reservoir 12. Alternatively, the condensed water, having exited the basket 20, may pass directly from the trap 22 into the reservoir 12 which may be in fluid communication with the trap 22. Alternatively, the apparatus 10 may not contain a trap 22 and the condensed water may pass directly into the reservoir 12.

In another embodiment, the apparatus 110 of the invention comprise a heater 118 located in a reservoir 112 (Figures 2a and 2b). The heater 118 is operable to heat the water in the reservoir 112 and to vaporise at least some of the water to create vaporised water (or steam). In operation, the vaporised water created in the reservoir 112 passes from the reservoir 112 via a proximal opening 16a of channel 116 to a condenser 114 wherein at least some of the vaporised water condenses. The condenser 114 may comprise a cooler, such as a fan-assisted cooler 114a, which is operable to cool a condensing surface of the condenser 114 and/or the ambient temperature in the channel 116. The condensed water, which is still close to the boiling point of water (i.e. about 100° C), then passes from a distal opening of the channel 116b to the rice R which may be held in a basket 120. The condensed water percolates through the rice R thereby cooking the rice R and leaching arsenic from the R. The condensed water containing some of the arsenic from the rice then exits the rice R and the basket 120 through at least one aperture (not shown) in the basket B. As depicted in Figure 2a, the condensed water may then be collected in a trap 122 from which it may be discarded or returned to the reservoir 112. Alternatively, as depicted in Figure 2b, the condensed water, having exited the basket 20, may pass directly from the trap 122 into the reservoir 112 since the trap 122 and reservoir 112 may be in fluid communication. Further alternatively, the apparatus 110 may not contain a trap 122 and the condensed water may pass directly into the reservoir 112.

As shown in Figure 3, in another embodiment, the apparatus 210 of the invention comprises a reservoir 212 in fluid communication with a condenser 214 via a channel 216, in which the condenser 214 may form part of the housing of the apparatus 210 such as the lid 224. A heater 218 may be located outside the reservoir 212, but may alternatively be comprised in the reservoir 212 as described above. In operation, vaporised water created by the heater 218 by vaporising water in the reservoir 212 passes through the channel 216 to the condenser 214. The condenser 214 can form part of the lid 224 of the apparatus and therefore may be cooled by the ambient temperature outside the apparatus 210, or by a cooler (not shown). The condenser 214 causes the vaporised water to condense without or without directly contacting the condenser 214 or lid 224. The condensed water then drops down to rice R, and percolates through the rice R thereby cooking the rice R and leaching arsenic from the R. The condensed water, containing some of the arsenic from the rice, then exits the rice R and is collected in a trap 222. The condensed water may then be discarded or returned to the reservoir 212. Alternatively, the apparatus 210 may not contain a trap 222 and the condensed water, having exited the rice B, may pass directly into the reservoir 212.

As shown in Figure 4, in another embodiment, the apparatus 310 comprises a condenser 314 which may be shaped to aid delivery of the condensed water to the rice R. Thus, the condenser 314 may

have a substantially convex shape. In operation, the heater 318 generates vaporised water by heating the water in the reservoir 312, and the vaporised water passes via channel 316 to the condenser 314. The heater 318 may be located outside the reservoir 312, but may alternatively be comprised in the reservoir 312 as described above. It will be noted that the channel 316 may be

5 formed by a space provided between the components of the apparatus 310 and the wall 330 of the apparatus. The vaporised water condenses by contacting the condenser 314, and the shape of the condenser 314 guides the condensed water to drop down to the rice R. The condenser 314 may be cooled by a cooler, such as a fan-assisted cooler (not shown). The apparatus 310 may further comprise a distributor, such as a plate 326, located between the condenser 314 and the rice R. The

10 plate 326 may comprise a plurality of apertures through which the condensed water can pass. The plate 326 is thus configured to evenly distribute the condensed water as it passes to the rice R. The rice R is held in a retainer, such as a basket (not shown). As described above, the condensed water percolates through the rice R, during which the rice R is cooked and/or arsenic is removed from the rice R. The condensed water, including arsenic removed from the rice, then exits the rice R and

15 passes back into the reservoir 312 wherein it can be re-vaporised and returned to the condenser 314 to repeat the cycle. The apparatus 310 may also comprise a shield 328 located between the rice R and the source of water to be vaporised, in this case the reservoir 312. The shield 328 may comprise at least one aperture through which the condensed water can pass and return to the reservoir 312. However, the shield 328 is also configured to prevent some or all of the vaporised

20 water from passing directly into the rice R, i.e. passing into the rice without being condensed by the condenser 314 and distributed to the rice R so as to percolate through it.

It will be appreciated that the apparatus of the invention may typically be used in a home kitchen setting. However, it will be appreciated that the apparatus may be scaled up for use in restaurant

25 kitchens and/or in industrial settings. This may be achieved by, for example, enlarging the percolator system, and wherein the components are configured differently, i.e. a heater or boiler may be adjacent to the apparatus and connected by pipes etc. The apparatus is also suitable for parboiling process wherein pre-soaked rice is steamed or boiled and then dried. Thus, the rice may instead be cooked using the apparatus described herein, or according to the method of the invention.

30 Parboiling is typically carried out on non-dehusked rice (rough rice), but also on wholemeal. On drying, the rice may be milled to remove husk and bran (for rough rice) or to remove bran (wholemeal).

By devising the present invention, the inventor has combined and maximized the benefits of

35 steaming particulate food such as rice, i.e. use of arsenic-free cooking water (i.e. condensed water), as well as a relatively large volume of cooking water to optimize As_i removal from rice. A standard laboratory Soxhlet system was used to develop and optimise an As_f-free circulating cooking water approach. In developing this invention, a Soxhlet apparatus was chosen as it generates and delivers freshly distilled and near boiling water directly to the rice. This fresh distilling removes all As_i that is

40 in the original water source, and subsequently in leached cooking water. The Soxhlet cooking procedure also has the added advantage in that the equipment and conditions are standardized and

readily repeated in any laboratory, providing a standardized way to assess how effectively As_i can be removed from any given rice sample.

Materials and Methods

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Rice sourcing & processing

Market rice was purchased from major UK retailers in the city of Belfast, or purchased online through UK retailers, i.e. all products tested were widely available to the UK populace. Of the 41 samples tested in this study, 2 were generically labelled as being from the EU, 11 from Spain, 6 from Italy, 5
10 from Thailand, 5 from France, 2 from Egypt, 1 from Japan, 1 from Australia, 1 from Lebanon, 1 from Pakistan, 1 from Turkey and 5 from the USA; with 13 being unpolished (wholegrain) and the rest polished.

Rice grain, fresh from the packet, was accurately weighed (either 10g or 2g) into a VWR Soxhlet
15 thimble and was then placed into an 25cm long and 3.5cm diameter Quickfit Soxhlet which was attached to a 250ml receiving flask at one end and a dimpled Vigreux 25cm condensing tube (14 rows of 3 dimples = 42 dimples in total), with the receiving flask sitting within an electrically heated mantle and supported by a retort stand and clamps. At the start of the experiment, the flask was filled with 200ml of deionized distilled water. Rice cooking was timed as per number of Soxhlet reflux
20 cycles, from 0-4, with 2 cycles sufficient to fully cook the rice. Average times for reflux cycles: 89 min. for 1st, 111 min. for 2nd, 135 min. for 3rd and 164 min. for 4th reflux. At the end of the appropriate cycle, the thimble containing rice was removed and freeze-dried, and then the rice powdered using a Retch PM100 rotary ball-mill using a zirconium oxide lined vessel and zirconium oxide grinding balls. Uncooked rice was similarly freeze-dried and milled.

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For arsenic speciation powdered cooked and uncooked rice were weighed accurately to a weight of 0.1g into 50ml polypropylene centrifuge tubes to which 2ml of 1% conc. Aristar nitric acid was added and allowed to sit overnight. Batches of 40 samples were prepared which also include a black and rice CRM (NIST 1568b Rice flour) which has the arsenic species As_i and dimethylyarsonic acid
30 (DMA) concentrations certified, then microwave digested in an CEM MARS 6 instrument for 30 min. at 95°C using a 3 stage slow heating program: to 55°C in 5 min. held for 10 min., to 75°C in 5 min., held for 10 min. to 95°C in 5 min., held for 30 min.). The digestate, on cooling, was accurately diluted to 10ml with deionized distilled water. A 1 ml aliquot was transferred to a 2ml polypropylene vial and 10ul ml of analytical grade hydrogen peroxide was added to convert any arsenite to
35 arsenate to facilitate subsequent chromatographic detection. For total As and multi-element analysis by ICP-MS, a more aggressive digestion procedure (heat to 95°C in 5 min. hold for 10 min. to 135°C then hold for 10 min., to 180°C then hold for 30 min.) was employed, with 2ml of concentrated Aristar nitric acid and 2ml hydrogen peroxide added and left to soak overnight before microwaving. Blanks and CRM NIST 1568b were included in each batch of 40 samples analysed.

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Chemical analysis

To speciate arsenic in rice the diluted 0.2% nitric acid digested rice solutions were run on a Thermo Scientific IC5000 Ion Chromatography (IC) system, with an Thermo AS7, 2x250mm column (and a Thermo AG7, 2x50mm guard column) and a gradient mobile phase (A: 20mM Ammonium Carbonate, B 200mM Ammonium Carbonate- Starting at 100% A, changing to 100% B, in a linear gradient over 15 min.) interfaced with a Thermo ICAP Q ICP-MS that monitored m/z^+ 75, using He gas in collision cell mode. The resulting chromatogram was compared with that for authentic standards; DMA, As_i , monomethylarsinic acid (MMA), tetramethyl arsonium (TETRA) and arsenobetaine (AB). Arsenic present under each chromatographic peak was calibrated using a DMA concentration series.

Total elemental As and other elements were measured also using the Thermo ICAP Q but in direct solution acquisition mode. Rhodium was used as an internal standard. All elements reported were present both in calibration standards and in CRM NIST 1468b with only elements with good CRM recoveries reported. Additional elements were also analyzed by bench-top XRF (Rigaku CG) on powdered samples. Again, only elements present in the CRM and with good analytical recoveries.

Results

The analysis of the As speciated CRM gave excellent recovery results, based on for $N=11$, with $90.1 \pm 4.4\%$ recovery for DMA and $85.5 \pm 3.3\%$ recovery for As_i , the only two species found in that CRM that were also detectable in the rice analysed, giving a sum of species recovery of 88.5%. The CRM had a certified concentration of 0.182 and 0.092 mg/kg As for DMA and As_i , respectively. The limits of detection (LOD) for both DMA and As_i (calculated from a DMA calibration) was 0.0028 ± 0.001 mg/kg DMA rice d.wt., $N=5$. All samples presented were above LOD for As_i and only a few samples were below LOD for DMA, and in this case $\frac{1}{2}$ LOD was used in statistical analysis of the data.

Initial studies on cooking 10g of one USA rice sample showed that the Soxhlet cooking method removed As_i to the extent of 45% at maximum cooking time at 4 reflux cycles, from a value of 0.057 mg/kg in the uncooked rice (Figure 5), with an appropriate reduction in sum of species and total As (Figures 5 and 6). As the sum of species by chromatography gave a higher recovery (88.5%) compared to total arsenic by ICP-MS following conc. nitric acid digestion (75%, see legend of Figure 6 above) this explains why the sum of species in the uncooked samples is higher (0.058 mg/kg) than the total As by ICP-MS (0.050 mg/kg). Also, for sum of species there is a drop at reflux 1 & 2, (Figure 5) but not for totals by conc. nitric acid digestion (Figure 6), this suggests that the conc. nitric acid method is suffering from matrix interference either in extraction or analysis, also confirmed by the lower CRM recovery. As speciation is more analysis is central to this study, i.e. in quantifying As_i , total As is only shown in the context of multi-elemental analysis by ICP-MS, the speciation data is not only much more valuable, but it is important to note that total As has limitations in the context of cooking studies. Consequently, only speciation analysis was conducted in subsequent experiments.

It was noted on inspection of the cooked rice that the top portion of the rice had a less dense texture than the bottom and the trial was repeated for 3 refluxes and the top 3cm and bottom 3cm of the rice removed from the 8cm long, 2.2cm diameter Soxhlet thimble and processed separately (Figure 7). Analyses of these top and bottom portions revealed differences in As_i content reduced to 0.013 mg/kg in the top section, a 77% reduction compared to cooked grain, as opposed to 0.033 mg/kg in the bottom section, a 42% reduction compared to uncooked grain. It was decided to trial a smaller (2g) quantity of rice to allow for greater room for expansion in the Soxhlet thimble on cooking. The comparison of As_i content when 2 or 10 g of rice was cooked verses the number of Soxhlet cycles is shown in Figure 5 where cooking 2g gave superior removal to cooking 10 g, and that removal was optimal for 2 g after 3 reflux cycles. Further comparison of 10 versus 2 g cooking was conducted on 20 different rice samples randomly selected (from a selection of 95 UK purchased grains) were analyzed after cooking at 10g uncooked rice per thimble, for 2 and 4 refluxes, and for 2g of uncooked rice at the 3 reflux stage, results presented in Figure 8. This showed that using 2g of rice resulted in a final cooked median concentration of 0.025 mg/kg As_i in the cooked rice for the 20 samples, a 72% reduction compared to uncooked rice, outperforming As_i removal for 10g at one reflux cycle more, with an 53% removal rate.

To examine in more detail the variability of both As_i and DMA removal on Soxhlet cooking an additional 20 samples of rice were added to the 20 presented in Figure 8, and the results presented in Figure 9. DMA is poorly removed on cooking, with the slope for the cooked versus uncooked comparison being just below the 1:1 relationship, with a median of 12% removal. For As_i , removal was considerable with a median As_i removal of the 40 samples being 59%. However, there was a range of As_i removals ranging from <20% to >80%, but it was some of the originally low As_i samples that had low removal rates, where grains originally high in As_i all had high removal rates on cooking. The consequence was that grains high in As_i at ~0.3 mg/kg d.wt. As_i could be reduced by a 1/3 to ~0.1 mg/kg, while grains at 0.2 mg/kg As_i could be reduced to below at or below 0.05 mg/kg (Fig. 5). Importantly, this approach works for wholegrain as well as polished rice (Figure 9), with highly efficient removal of As_i from wholegrain, median 66%. Note that total As is a poor surrogate for As_i in cooking experiments because it is only As_i that is preferentially removed on cooking.

For key trace- and macro- elements measured in the trials (Figure 6) it was only potassium for which there was substantial removal on Soxhlet cooking, ~50% after 4 reflux cycles, with respect to nutrients. Importantly there was no loss of the nutrients phosphorus, sodium, magnesium, calcium, manganese, iron cobalt, copper or zinc. Sodium, magnesium and calcium increased on cooking which suggests that these elements are derived from either the glass or the Soxhlet thimbles as all the water is freshly distilled, and/or that there were reductions in cooked rice biomass (i.e. that some soluble components were removed such as starch) compared to uncooked, and/or that no leaching of these elements occurred on cooking, leading to elevated levels in cooked compared to uncooked rice.

Discussion

Mitigating As_i levels in rice is essential as this commodity is the major global source of this carcinogen and with consumption predicted to cause significant increases in excess lifetime cancer burdens, in the order of ~1-2 in 1,000, for the highest rice eating communities. Given the currently unpromising use of breeding/cultivar selection and agronomic strategies to provide solutions, the finding here that re-thinking of how rice is cooked, using a continual flow of clean cooking water versus traditional static systems, is a major breakthrough, enabling up to 80% of the As_i content of uncooked grain to be removed on cooking, much higher than the use of standard static cooking water or steaming based systems. Furthermore, this continual flow system offers a way of assaying which rice is amenable to have As_i removed on cooking, and using a Soxhlet based system, the method is also standardized and repeatable in any laboratory and is not reliant on the purity of water used because delivery of cooking water is through distilled steam.

Although this method was developed around Soxhlet, for standardization, household or commercial scale cookers could adopt the same approach, optimizing cooking times as the Soxhlet based approach is dependent on steam generation from cold water in a non-thermally blanketed Soxhlet system, which could be made more efficient with respect to speed of cooking etc.. The development of commercial approaches based on continuously flushing rice with arsenic free cooking water would have application in baby rice manufacture, for example, as baby rice is of particular concern with respect to human exposures and baby rice is a product where grain is pre-cooked, dried and milled, much the same as the sample preparation for analysis here. Rice milk is similarly problematic being elevated in As_i and is fed to lactose intolerant children in quantities that raise concern. Rice milk is prepared from cooked rice and manufacturing processes could be optimized for As_i cooking using the continual cooking water flow principle demonstrated here. It is not difficult to envisage that large scale rice cookers for baby rice and rice milk manufacture could be based either on the distillation approach used by Soxhlet or with a continual flow of externally pre-heated water passing through the rice, through the distillation approach is probably more energy and water efficient and does not rely on having low arsenic in the water supply. With baby rice if elemental nutrients (i.e. potassium) do need supplementation this is easy to do and indeed many baby rice products are nutrient and vitamin fortified. Vitamin removal was not assessed here and again may need to be investigated with respect to commercial production of products such as baby rice, and as rice is an important source of soluble B-vitamins, with vitamin B2 known to be leached from rice on cooking dependent on processing methodologies.

Non-milled, pre-cooked rice is becoming an important market in the prepared food business, from stand-alone precooked boiled rice to boiled rice in pre-packed Asian & S.E. Asian foods, and in products such as pre-cooked baby food jars. For all these products continual cooking water flow cooking approaches could be applied to lower As_i to consumers. Cooked rice texture using continual flow cooking, not assessed here, while unimportant for milled baby rice, would be important for non-milled pre-cooked products, but manufactures could optimize rice type/source and cooking

conditions to optimize final texture of their product. Home cooking continual flow would need the specific product design, but should be achievable, and given that there is already a wide penetrance of specific rice cookers for domestic use, based on steaming, so there is a market for specific rice cookers. The key to a home based continual rice cooker development simply needs a steam
5 condensers unit to supply water to rice suspended in a basket with a bottom receiver (pot) directly heating the water. Condensers could be based on water/ice cooling, on thermal properties of materials used for a lid with the design of the inside of the lid optimized to deliver stream of condensing water to the rice, or on electro-thermal cooling technologies for the lid/condenser. Home-based appliances for water/ethanol extraction of essential oils from plant-based material are
10 already available and could be readily adapted, to lower cost and to increase efficiency.

In situ speciation shows that grain As_i is either as free As_i or as sulfhydryl complexed As_i . It is not clear why grains with more As_i release more As_i on cooking as compared to those low in As_i , but perhaps it is grain geometry, i.e. that As_i in the outer portions of the grain are more easily removed
15 than those in the inner portions. It is known that As_i is more elevated at the grain surface than in the centre.

The finding that As_i is readily leached from rice while DMA is not conforms well with what is known with their rice gut availability where As_i has a high gut availability where DMA does not. The fact that
20 As_i is readily leached from wholegrain and well as polished rice is also important. Although not tested here, if rice bran As_i is readily removed using continual flow of replenished cooking water then this product which is highly elevated in As_i may be made suitable for the human food-chain, given that in many aspects it is a highly nutritious product whose health and commercial value is negated by its As_i content.

25 In the present disclosure, the term "about" is meant to indicate that the value of the parameter to which the term pertains is the recited value, or that said value can vary within a certain range depending on the margin of error of the method or apparatus used to evaluate the parameter. For example, the margin of error may range between $\pm 0.5^\circ \text{C}$ to $\pm 5^\circ \text{C}$ in respect of temperature values,
30 and ± 1 minutes to ± 10 minutes in respect of time values.

The invention is not limited to the embodiments described herein but can be amended or modified without departing from the scope of the present invention as defined by the appended claims.

Claims

1. An apparatus for cooking a particulate food, the apparatus comprising:
a condenser for condensing vaporised water, and
5 a retainer for holding the particulate food,
wherein the retainer is arranged to receive the condensed water and to allow the condensed water to percolate through and exit the retainer.
2. The apparatus of Claim 1, further comprising a heater for vaporising water.
- 10 3. The apparatus of Claim 2, further comprising a water source in fluid communication with the heater.
4. The apparatus of Claim 3, wherein the water source is a reservoir comprised in the
15 apparatus.
5. The apparatus of Claim 3 or 4, wherein the apparatus further comprises a channel to allow passage of water and/or steam between the water source and the condenser, the channel terminating in a proximal opening adjacent the water source and a distal opening adjacent the
20 condenser.
6. The apparatus of any one of Claims 3 to 5, wherein the heater is arranged to impart heat to the water in the water source.
- 25 7. The apparatus of Claim 5 or 6, wherein the heater is arranged to impart heat to the water in the channel.
8. The apparatus of any one of the preceding claims, wherein the condenser comprises a condensing surface with which the vaporised water can directly or indirectly contact.
- 30 9. The apparatus of Claim 8, wherein the condensing surface comprises a cooler to cool the condensing surface.
10. The apparatus of Claim 9, wherein the cooler is a fan-assisted cooler.
- 35 11. The apparatus of any one of the preceding claims, wherein the apparatus further comprises a distributor to distribute the condensed water to the particulate food in the retainer.
12. The apparatus of Claim 11, wherein the distributor is disposed at or adjacent the distal
40 opening of the channel.

13. The apparatus of Claim 11 or 12, wherein the distributor further comprises a plate located between the condenser and the retainer, wherein the plate comprises a plurality of apertures through which the condensed water can pass.
- 5 14. The apparatus of any one of the preceding claims, wherein the retainer is a basket comprising at least one aperture through which the condensed water can exit the basket.
15. The apparatus of Claim 14, wherein the at least one aperture is configured to inhibit or prevent the entry of vaporised water into the basket.
- 10 16. The apparatus of any one of Claims 3 to 15, wherein the apparatus further comprises a shield located between the retainer and the water source, wherein the shield comprises at least one aperture through which the condensed water can pass and wherein the at least one aperture is configured to inhibit or prevent entry of vaporised water into the particulate food.
- 15 17. The apparatus of any one of the preceding claims, wherein the apparatus further comprises a trap to collect condensed water that has exited the particulate food.
18. The apparatus of Claim 17, wherein the trap and the reservoir are in fluid communication.
- 20 19. The apparatus of any one of Claims 4-18, wherein the reservoir is arranged to collect condensed water that has exited the particulate food.
20. A method for cooking a particulate food to remove at least some arsenic from the particulate food, the method comprising:
- 25 (i) condensing vaporised water; and
(ii) percolating the condensed water through the particulate food until the particulate food is cooked and/or until a pre-determined quantity of arsenic has been removed from the particulate food.
- 30 21. The method of Claim 20, wherein said method additionally comprises vaporising water.
22. The method of Claims 20 or 21, wherein said method additionally comprises heating water in a reservoir to produce said vaporised water.
- 35 23. The method of Claim 22, wherein said method additionally comprises returning the condensed water to the reservoir after said condensed water has percolated through the particulate food.
24. The method of any one of Claims 20 to 23, wherein said method is performed using the
- 40 apparatus of any one of Claims 1-19.

25. The method of any one of Claims 20 to 24, wherein, in the percolating step, the condensed water is percolated through the particulate food for 1-60 minutes.
26. The method of any one of Claims 20 to 25, wherein the pre-determined quantity of arsenic is
5 at least 30% of the arsenic present in the particulate food prior to cooking the particulate food.
27. The method of any one of Claims 22 to 25, wherein the method further comprises a step of
collecting the condensed water that has percolated through the particulate food in a trap in fluid
communication with the reservoir, or directly in the reservoir, and recirculating the condensed water
10 by vaporising said condensed water.

Figure 1

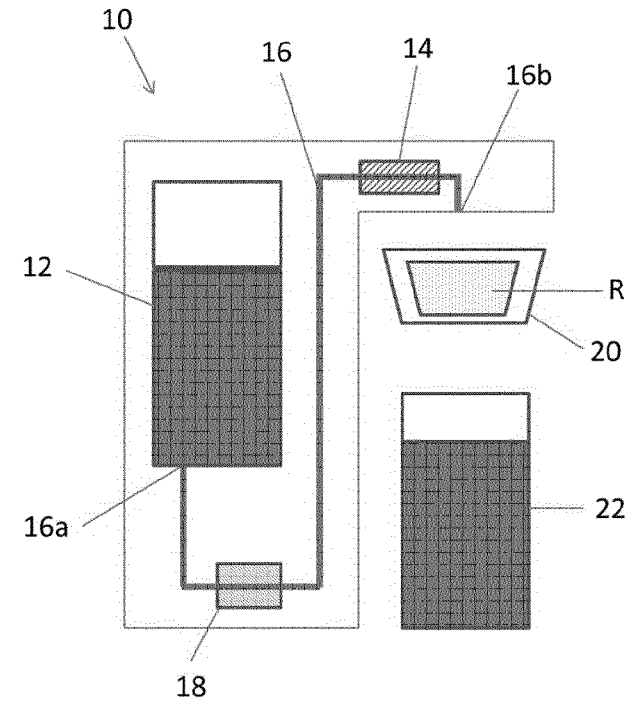


Figure 2a

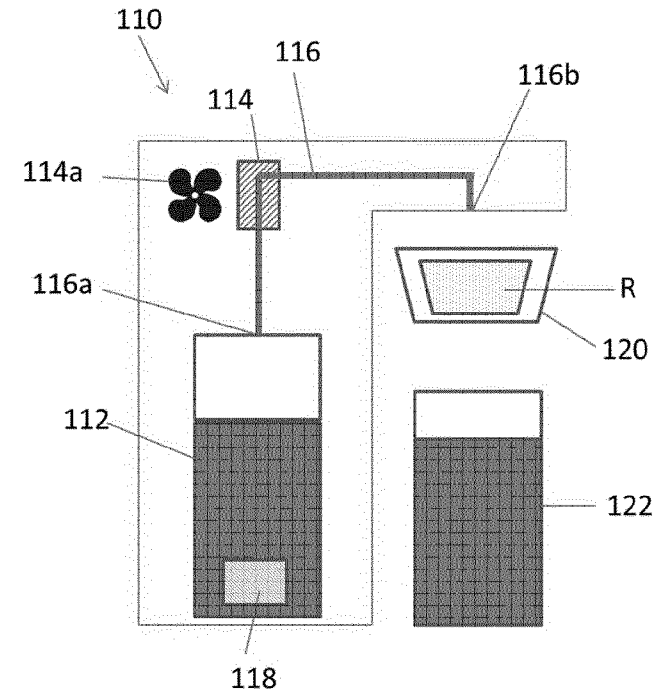


Figure 2b

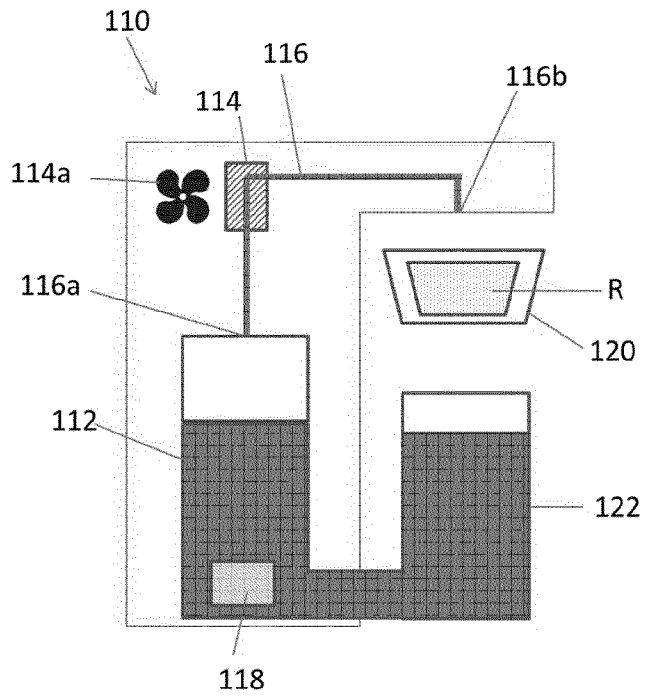


Figure 3

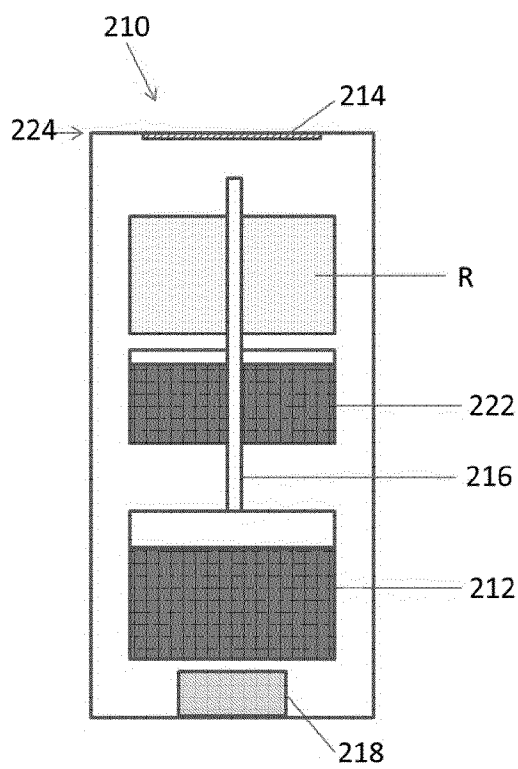


Figure 4

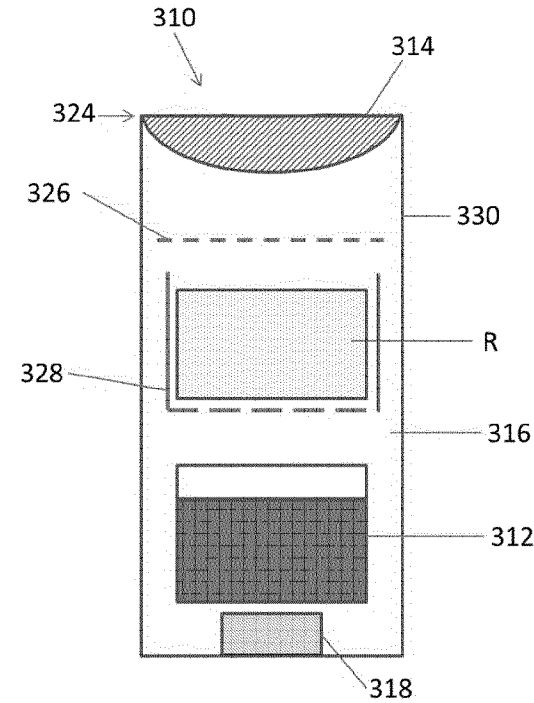


Figure 5

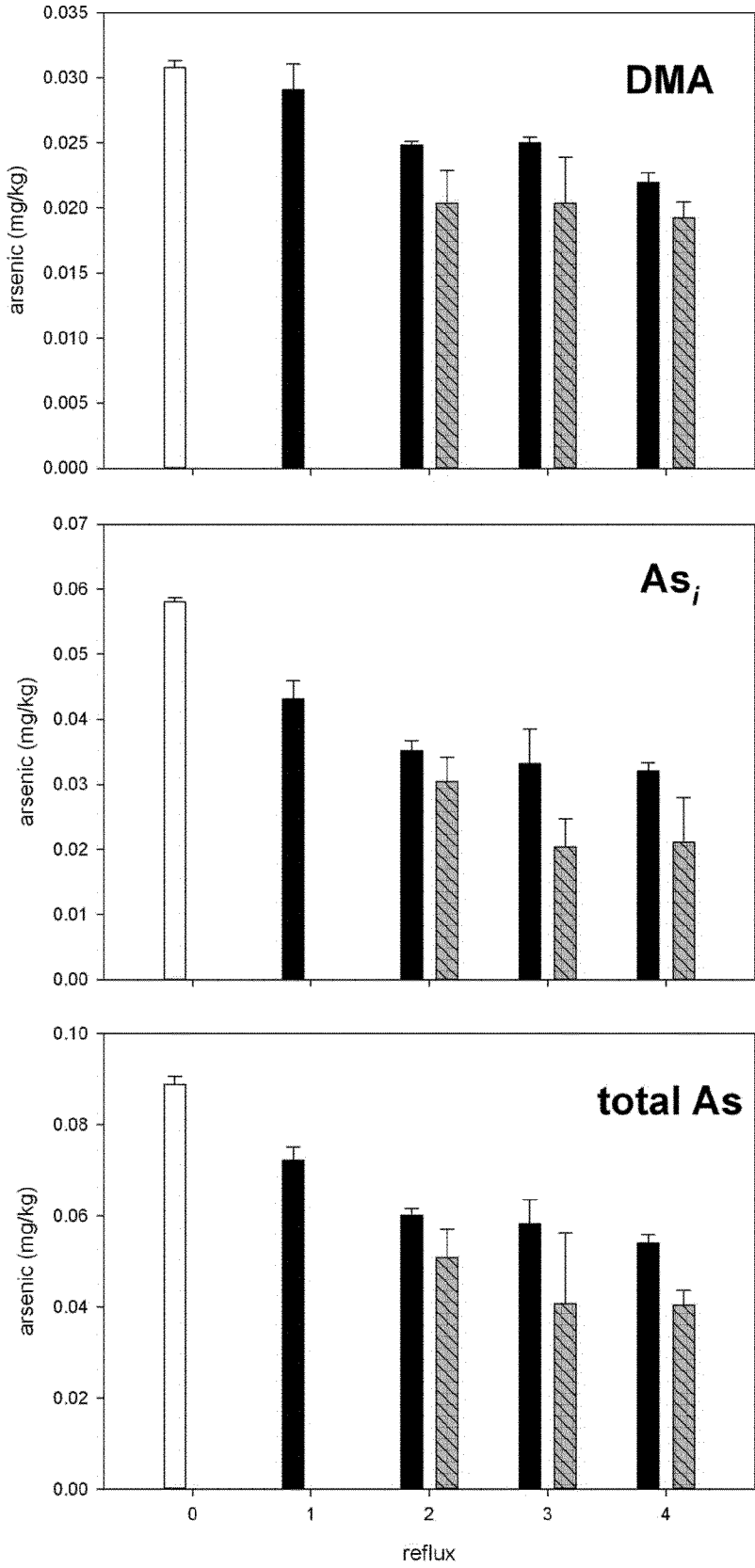


Figure 6

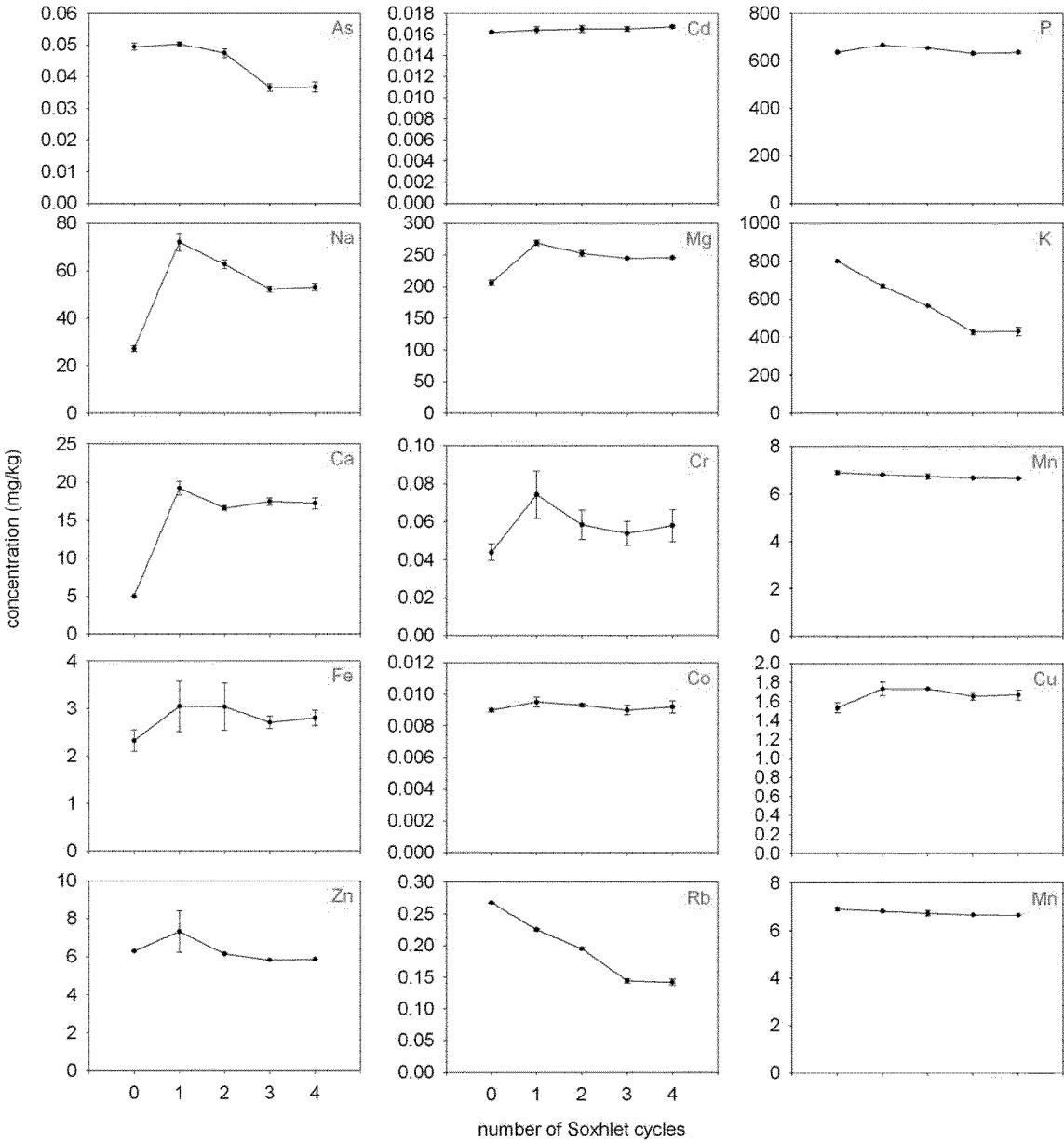


Figure 7

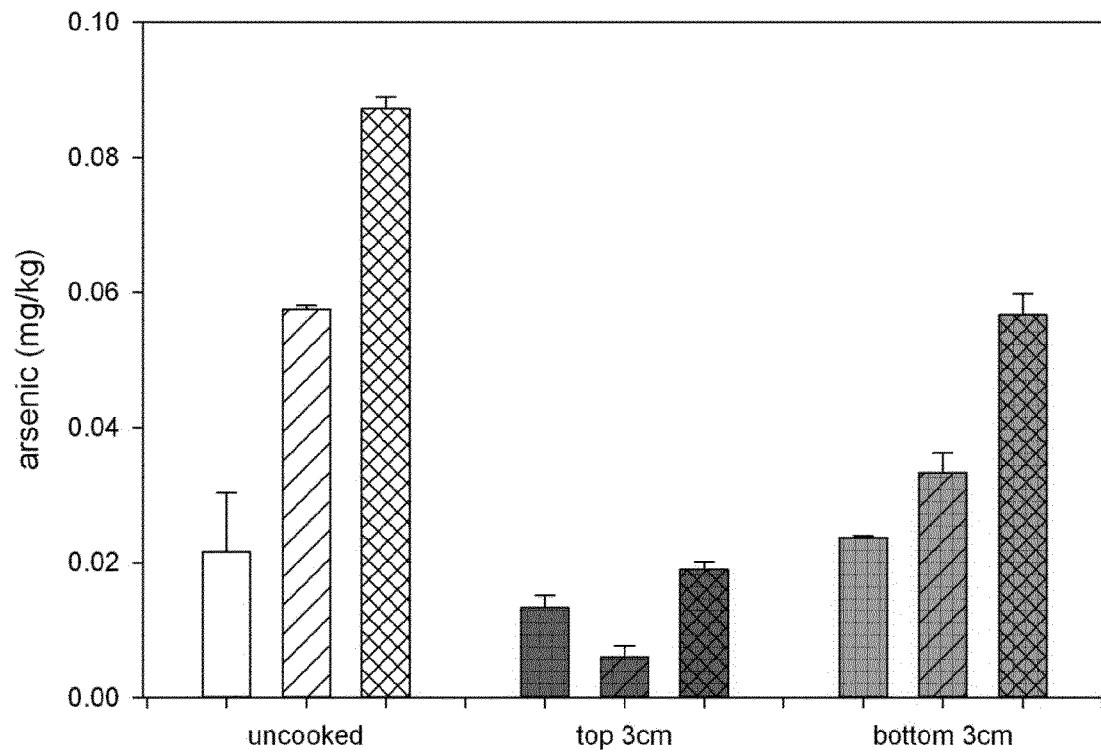


Figure 8

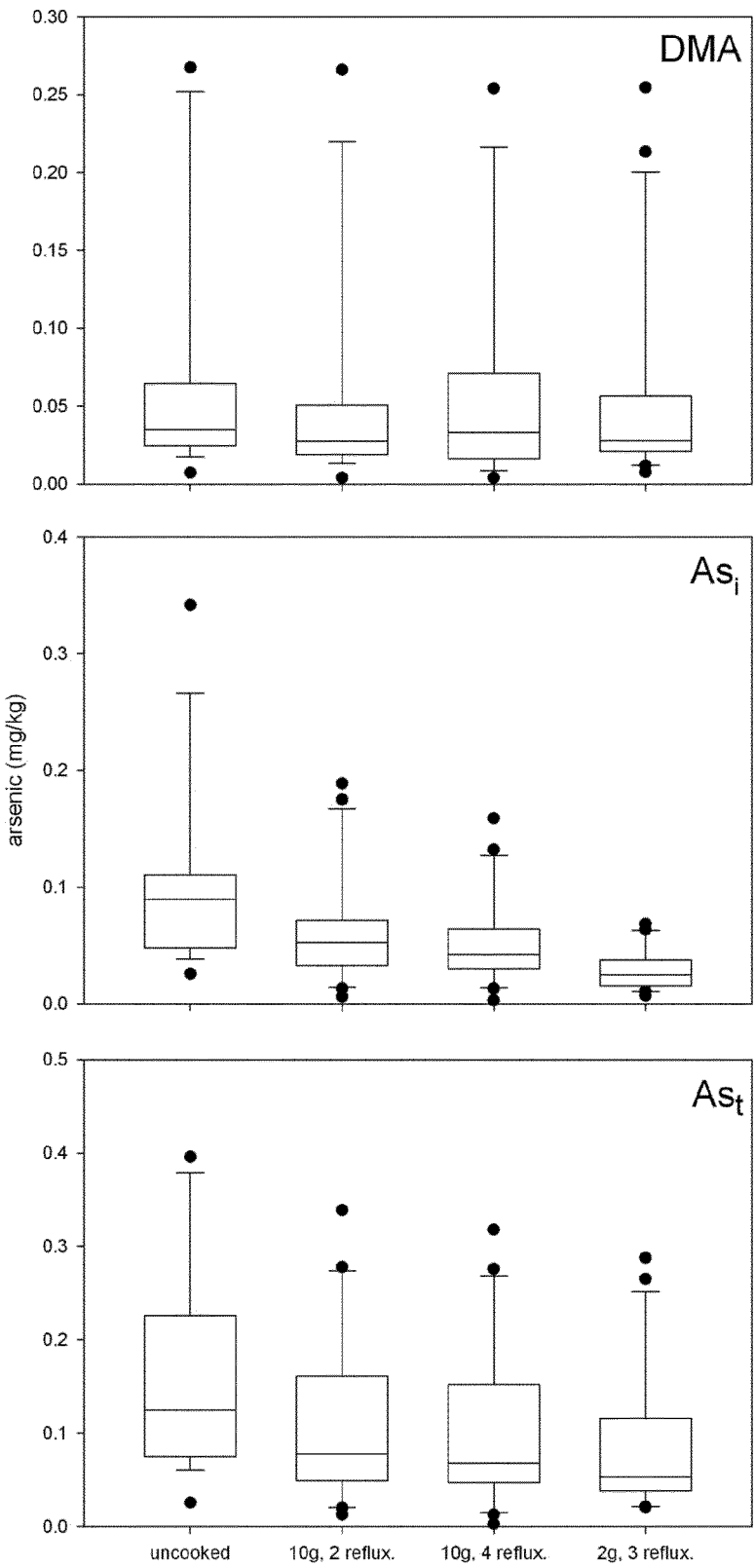
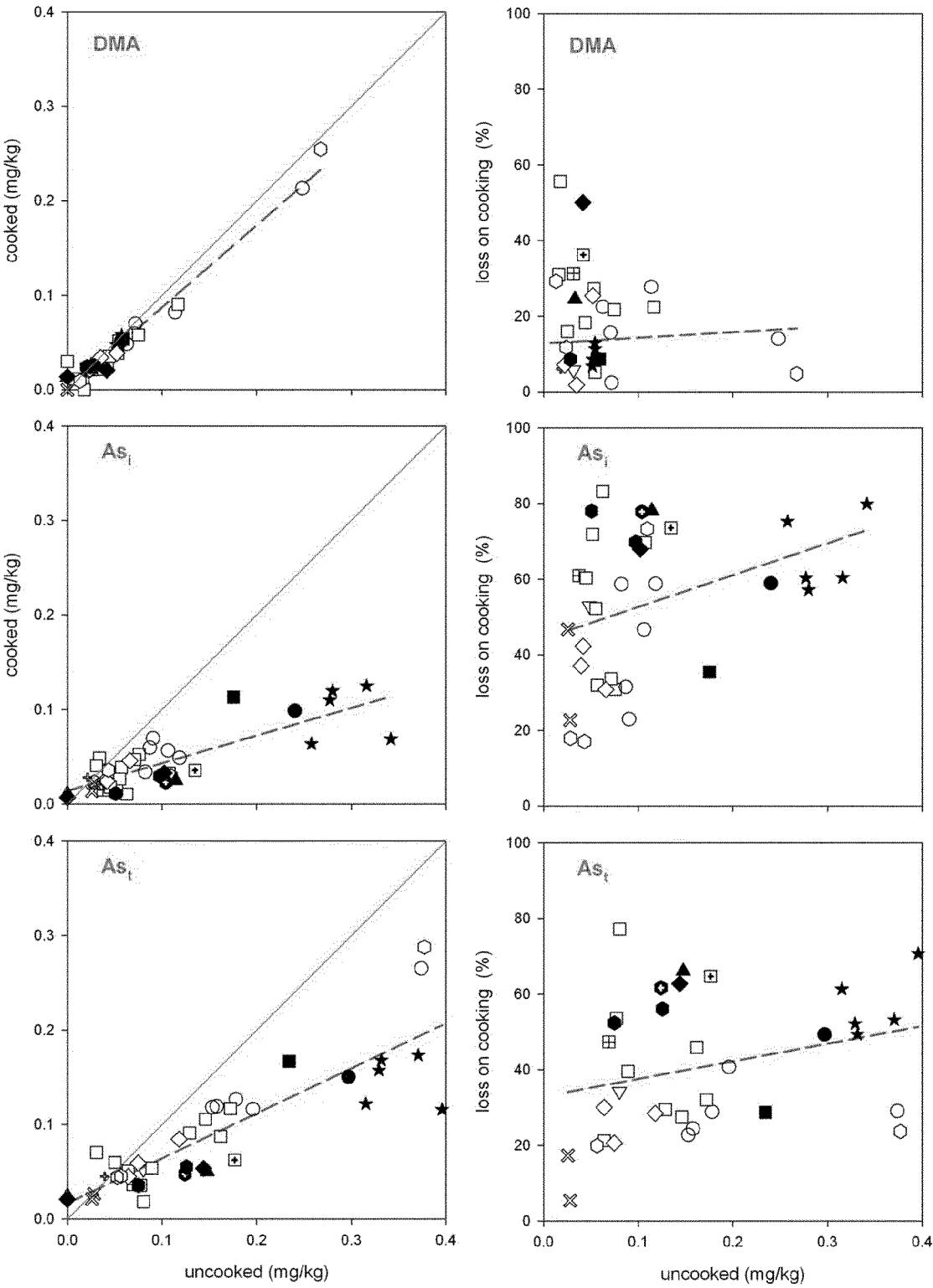


Figure 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/052853

A. CLASSIFICATION OF SUBJECT MATTER
INV. A47J27/04 A47J27/62
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A47J A23L

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

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

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/190221 A1 (TSE TUNG H [HK]) 16 August 2007 (2007-08-16) paragraph [0014] - paragraph [0018]; figures 1,2	1-27
X	----- DE 25 41 374 A1 (PFEIFFER KLAUS ING GRAD) 24 March 1977 (1977-03-24) figure 1	1-27
X	----- WO 2013/098698 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]) 4 July 2013 (2013-07-04) figures 3-5	1-27
X	----- US 4 649 898 A (MARTINSON EDWARD D [US]) 17 March 1987 (1987-03-17) figure 1	1-27



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/052853

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
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DE 2541374	A1	24-03-1977	NONE	

WO 2013098698	A1	04-07-2013	NONE	

US 4649898	A	17-03-1987	NONE	
