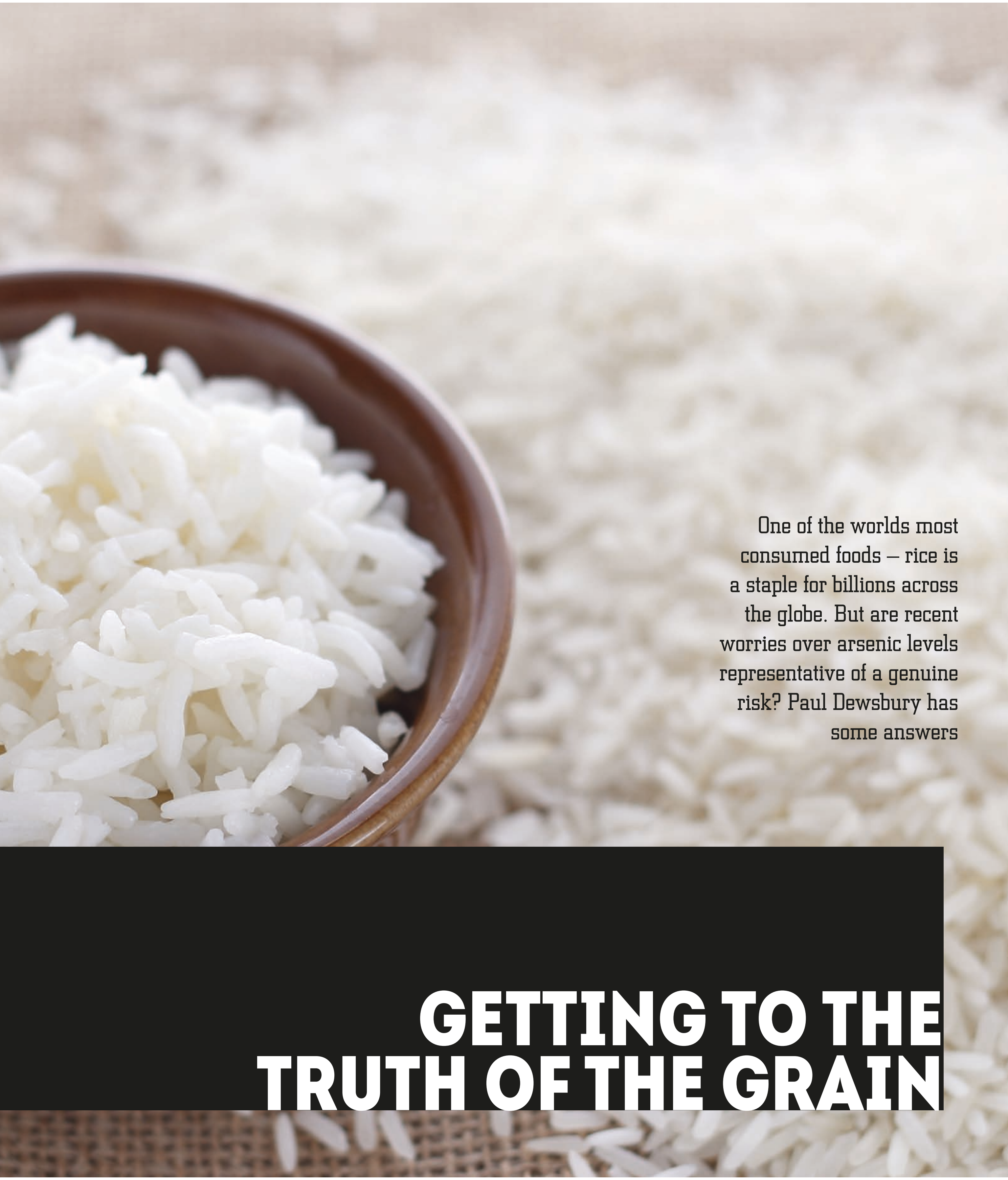

One of the worlds most consumed foods – rice is a staple for billions across the globe. But are recent worries over arsenic levels representative of a genuine risk? Paul Dewsbury has some answers

GETTING TO THE TRUTH OF THE GRAIN

Rice is a staple food for more than 3.5 billion people around the world. Precisely what those grains of rice contain is therefore exceedingly important. Recently, there has been a relatively substantial media furor around the levels of arsenic (As) – specifically inorganic arsenic (Asi) – present within rice and the possible threat this poses to human health. It turns out that rice is a major source of food for many, but also the primary source of carcinogenic Asi in our diets.

As is present throughout the environment, being a natural component of the Earth's crust, and is acutely toxic in its inorganic form. Fortunately, we rarely encounter it at sufficient levels to pose a real threat, and in those instances where we might come into contact with sufficiently high levels of Asi, there are regulations in place to safeguard health. Or at least there should be: while there are established acceptable levels of Asi for drinking water or the air, until recently there were no suitable regulations European Union (EU) or United States of America (US) applicable to its levels in food. However, the scales are now tipping in favour of the consumer with the announcement of a new legislation in Europe on the issue of As in rice.

Unlike many other high profile grains, rice is grown under flooded and thus anaerobic conditions. This environment promotes the release of Asi that would otherwise be stable or bound to other soil minerals. This increases the Asi phytoavailability: rice is capable of accumulating up to 10 times more Asi than other high profile grains like wheat and barley. The two-fold effect here is the release of Asi into the paddy field water and the subsequent uptake of this soluble form into the rice plants. Once absorbed, Asi becomes embedded in the roots, shoots, leaves, and seeds – specifically accumulating in the husk (which is left intact in brown rice).

The high gut bioavailability of Asi compounds is an issue, and just 70–180mg taken orally is considered a fatal dose. Although its level in food, like rice, is far below a lethal concentration, this does not mean it is without risk. Chronic, sub-lethal exposure to Asi can cause numerous health problems, often taking years to develop depending on the exposure level, and includes skin lesions, cancer, developmental toxicity, neurotoxicity, cardiovascular diseases, abnormal glucose metabolism,

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and diabetes. There is also evidence that it is capable of having a negative impact on fetal and infant development, particularly reduced birth weight[1]. While Asi is more toxic than its organic form, the speciation of Asi can affect the degree of toxicity: Asi in a trivalent (III) state for example, is deemed more toxic than the pentavalent (V) state. Arsenic compounds in this trivalent state are so toxicologically potent due to their ability to generate reactive oxygen species (ROS) and reactivity with sulphur-containing compounds *in vivo.* However, humans are rarely exposed to a single form, instead coming into contact with a mixture of both.

> "It turns out that rice is a major source of food for many, but also the primary source of carcinogenic Asi in our diets"

The European Food Safety Authority (EFSA) has estimated[1] that high consumers of rice, such as certain ethnic groups, have a daily dietary exposure of Asi of about 1µg/kg bodyweight (bw) per day[1]. Worryingly, dietary exposure to Asi for children under three years of age is estimated to be from two to three-fold higher that of adults. Exposure data from two different studies show Asi intake ranging from 0.5 to 2.66µg/kg bw per day in children. Add to this the fact that rice porridge is often

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used for weaning, and that the rice-based products market (that includes crackers and cereals) is growing, and the risk of poisoning is substantially elevated in this subpopulation. The UK Food Standards Agency (FSA) even proposed[2] that children under the age of four-and-a-half should not drink rice milk.

Despite the facts around Asi toxicity and its presence within such a globally popular staple food like rice, the lack of suitable regulations governing acceptable limits is a major concern. The Joint Food and Agriculture Organization of the United Nations (FAO)/ World Health Organization (WHO) Expert Committee on Food Additives (JECFA) recently announced guidelines[3] for Asi in rice, stating that the level of arsenic in rice should not exceed 200µg/kg. However, this has already been called into question and the ESFA has suggested it be reduced. It was noted that speciation data for different foods are still required in order to lend support to a more complete dietary exposure assessment to better define and assess the risk of Asi.

In an effort to provide robust data on the specific levels of Asi, a team of researchers from the Institute for Global Food Security (Queen's University Belfast), conducted a survey of a broad selection of rice-based products[4] to compliment a recent US Food and Drug Administration (FDA) study[5]. The team examined 29 samples of commercial baby rice, 53 samples of commercial rice cereals, and 97 samples of commercial rice crackers belonging to 21 of the most popular commercial brands or manufacturers from the EU market. These were compared to 85 samples of commercial baby rice, 105 samples of rice cereals and 199 samples of rice crackers included in the US FDA study. The results were put in context of exposure risks to infants and young children.

An ion chromatography (IC) system (Thermo Scientific Dionex ICS-5000+ system) with a 2 x 250mm column (Thermo Scientific Dionex IonPac AS7 column; Thermo Scientific Dionex IonPac AG7, 2 x 50mm guard column) and gradient mobile phase interfaced with an ICP-MS (Thermo Scientific iCAP Q Series) were used to measure levels of Asi and two additional species – dimethylarsinic acid (DMA) and monomethylarsonic acid (MMA). The limits of detection (LOD) for both DMA and Asi (calculated from a DMA calibration) was 3µg/kg.

The levels of Asi in baby rice ranged from 56 to 268µg/kg. Results highlight that 14% of the baby rice samples exceeded the JECFA proposed Asi maximum level for rice. The baby rice brand with the highest Asi concentration reached a median of 190 µg/kg. Rice cereal Asi concentration ranged from 8 to 323µg/kg, with one brand reach up to 1.6 times the JECFA maximum level (median of 234µg/kg). The Asi concentrations in rice crackers ranged from 19 to 212µg/kg. The rice cracker brand with the highest Asi concentration (median of 205µg/kg) also exceeded JECFA proposed maximum levels.

With children consuming a higher amount of rice per unit of body weight than an adult, these figures become especially concerning. While there were slight differences between rice from the EU and US, the results from the study echo those found in the FDA study. The FDA examined 1,300 samples of rice and rice products and found that the average levels of Asi for the various rice and rice products ranged from 0.1 to 7.2 µg per serving[6].

The FDA do not offer a solution to this concern, but the data in this analysis from the Institute for Global Food Security demonstrate that Asi in rice represents a risk that cannot be overlooked. The authors conclude that there is an urgent need for regulatory limits on Asi in food, particularly rice-based products.

The FDA Commissioner Margaret Hamburg, has previously said that: "The FDA is committed to ensuring that we understand the extent to which substances such as As are present in our foods, what risks they may pose, whether these risks can be minimised, and to sharing what we know." She went on to offer the advice that: "…consumers should continue to eat a balanced diet that includes a wide variety of grains – not only for good nutrition but also to minimise any potential consequences from consuming any one particular food"[6].

The FDA is working with partner agencies (including the U.S. Department of Agriculture, the Environmental Protection Agency, the National Institute of Environmental Health Sciences, and the Centers for Disease Control and Prevention), scientists and consumer groups to offer further insight into the issue of As in rice.

As of June 2015, the European Commission amended acceptable levels of Asi in foodstuffs[7]. They published regulation (EU) 2015/1006 amending annex to regulation (EC) no 1881/2006 regarding the maximum levels of Asi in foodstuffs. The limits of Asi (sum of As(III) and As(V)) took into account rice and rice-based products, as well as the infants and children:

- Non-parboiled milled rice (polished or white rice) 0.20mg/kg
- Parboiled rice and husked rice 0.25mg/kg
- Rice waffles, rice wafers, rice crackers and rice cakes 0.30mg/kg
- Rice destined for the production of food for infants and young children 0.10mg/kg

These maximum levels are due to be applied from January 2016.

The principle action to be implemented needs to be the agreement of maximum safe levels of Asi in rice and rice-based products. The EU have recently taken steps to control the Asi levels in food, yet both EU and US regulatory bodies continue to work on this issue – it is hoped any future limits will be set these below those outlined in the JECFA guidelines. This is an important step to protect not only those populations that consume high levels of rice (countries in south-east Asia for example), but specifically children, who are at a higher risk due to their greater levels of exposure. Based on the existing limits, and the data presented from the survey of rice-based products, it seems clear that many products already contain unacceptable high levels of Asi. Further analysis will be required to see just how large of problem this may be.

The media attention that As in rice has received has highlighted this unseen threat, but also brought to the attention of many a simple means of reducing the levels of As in rice. Research has shown that by repeatedly flushing cooked rice with fresh hot water, much of the As in the rice can be removed[8]. Clearly this is only a short term solution, yet the technique employed could potentially be applied to reduce As levels in the production of rice-based products on a more industrial scale.

Longer term solutions come in the form of breeding 'As-resistant' strains of rice from those that naturally accumulate lower amounts of As[9]. Genetic engineering could also be employed to reduce the accumulation of As in rice by interfering with the plant's transport pathways. These methods are still primarily restricted to the realms of theory, or at best are fields of research in their infancy, yet may be promising options to make As in rice less of a risk.

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