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Improving Rice Dietary Fibre Content and Composition for Human Health

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Summary Soft textured rice is the major source of calories in the diet of most South East (SE) Asian countries. However, it is most often consumed after polishing which removes the bran and embryo and hence most of the vitamins, minerals and dietary fibre (DF) are lost. Consequently, white rice comprises over 90% starch with only trace amounts of DF and is rapidly digested in the human gastrointestinal tract, resulting in a high glycaemic index (GI). The excessive consumption of high GI foods is associated with increased risks of a range of chronic diseases including type-2 diabetes, cardiovascular disease (CVD) and some types of cancer. Furthermore, the incidence of these conditions is dramatically increasing in areas where white rice is the staple food, notably Asia, with the prevalence of diabetes in SE Asia alone predicted to reach 120 million by 2030. It is therefore necessary to develop rice lines in which high energy content is combined with low GI. This may be achieved by combining acceptable levels of resistant starch (RS) with an increased content of the cell wall derived-dietary fibre components.

Key Words dietary fibre, glycaemic index, type-2 diabetes, resistant starch, human health

Globally established sustainable development goals include the sustainable production of healthy nutritious foods (https://www.un.org/sustainabledevelopment/sustainable-development-goals). Although malnutrition is still a problem globally, the major impact of food on the health of an increasing proportion of the world's population relates not to restricted access but to over-consumption. Consequently, a rise in chronic diseases is associated with rapid urbanization and industrialisation and the adoption of a western diet, with consumption of highly refined foods which are rich in readily digested carbohydrates and fats, combined with an increasingly sedentary lifestyle (*1*). The role of food in the prevention of chronic diseases has long been recognised (*2*) with a particular emphasis on consumption of fruit and vegetables. However, cereals remain the staple foods in most countries and improving their health benefits by processing or genetic improvement is therefore the most attractive and cost-effective option to meet this challenge.

Cereals are also important sources of dietary fibre (DF) with a number of approved health claims in Europe (European Food Safety Authority [EFSA]) and the US (Food and Drug Administration [FDA]). Established health benefits include lowering blood pressure and serum cholesterol (and hence the risk of CVD), improving insulin sensitivity (and hence reducing the risk of type 2 diabetes) and reducing the incidence of bowel and breast cancers (*3–8*).

White rice is produced by removal of the outer DF-rich layers of the grain to leave the starch-rich endosperm. A strong correlation has been established between the consumption of white rice and type 2 diabetes (*9*), while (*10*) reported that increasing the fibre content of white rice resulted in a reduction in the glycaemic index which would be expected to reduce the risk of type 2 diabetes. The mechanism for the effect of dietary fibre on GI is not completely understood, but it may reduce the rate of food digestion and nutrient absorption due to effects on food structure and breakdown and, in the case of soluble fibre, by increasing the viscosity of the digesta.

Fibre intake is well below nationally-set recommended levels in many countries and fibre intake has not increased despite a large body of evidence linking dietary fibre intake with reduced risk of various chronic diseases (*11* and refs therein). Interestingly, there is a level of uncertainty regarding the level of type-2 diabetes in Japan based upon reported meta-studies. Mukai et al. (*12*) point to an increasing prevalence of type-2 diabetes in the Japanese population related to increases in obesity and reduction in physical activity. Nanri et al. (*13*) report that increased consumption of white rice in Japanese women is linked to an increased risk of developing of type-2 diabetes, but this is not the case in men. However, Goto et al. (*14*) and colleagues Charvat et al. (*15*) and Goto et al. (*16*) point to the population structure in Japan as being of importance. Although the absolute number of cases of type-2 diabetes is increasing in Japan this might be due to the aging population.

Although there would be clear benefits in increasing the consumption of whole (brown) rice products instead of refined white rice, these products have low

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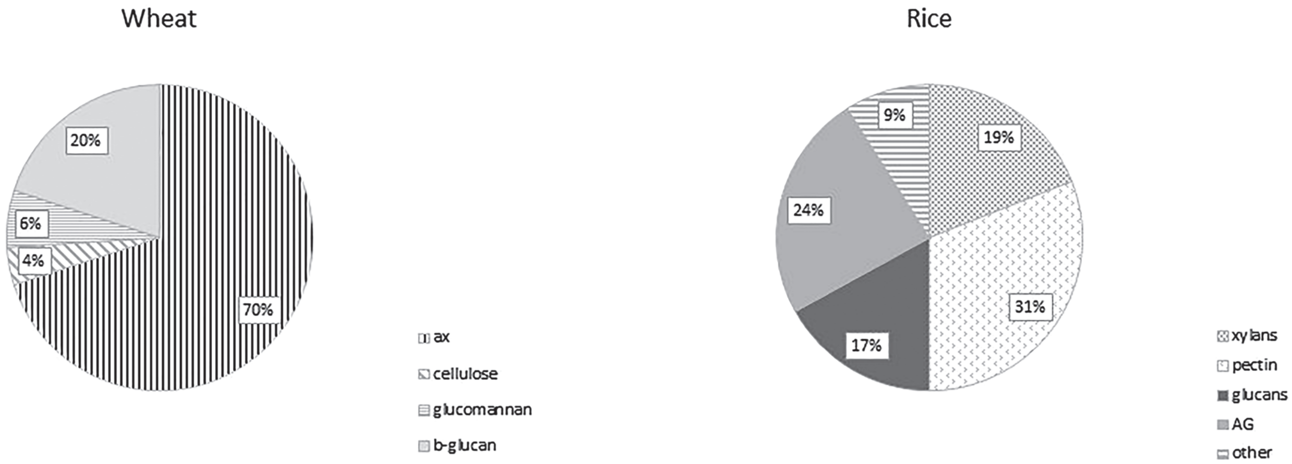

Fig. 1. Comparison of cell wall polysaccharide composition of wheat (white flour) and rice (polished). Predicted cell wall polysaccharide composition of wheat (white flour), based on literature values. Rice (polished) based on (authors unpublished data). AX (arabinoxylan); AG (arabinogalactan).

consumer acceptability, partly due to cultural factors but also because they differ in taste, colour and texture from conventional products. Consequently, reducing the GI of white rice by decreasing the digestibility of starch and increasing the content of DF, while maintaining good processing and organoleptic properties (and hence high consumer acceptability) is an important goal for developing new healthier types of rice.

GI is affected by a number of factors including the (a) percentage of amylose versus amylopectin represented in starch and (b) the proportion of "resistant starch" (RS). RS is a small fraction of the starch which is resistant to digestion in the small intestine, escapes hydrolysis and passes through the small intestine. It is fermented by the resident microflora in the colon which produce short chain fatty acids (SCFA) which have suggested health benefits in preventing non- communicable diseases (NCDs) and cancer (*17*, *18*). There are five types of RS reported. RS1 is a type due mostly to the presence of intact cell walls in the food matrix found in whole and partly-milled grains and seeds making them impenetrable to digestion. RS2 is characteristic of any native starch granule with B-type crystallinity, ungelatinized resistant granules with a higher degree of resistance to α-amylases found in high amylose starches. RS3 is generally referred to RS resulting from the retrogradation of starch granules found in cooked, cooled and refrigerated samples, which occurs due to prolonged exposure to and/or repeated moist heat processing. RS4, is typically chemically altered starches making them less susceptible to digestion in vitro due to the chemical modifications. RS5 results from amylose-lipid complexation, mostly due to phosholipid interaction with starch.

Resistant starch, as described above, can result from a number of effects, including an increased proportion of amylose. However, amylose content is also an important determinant of cooking quality as it influences gel consistency and gelatinization temperature, and hence hardness, and cooking time. Furthermore, although high amylose would be preferred for low GI, it is known to contribute to a harder textured rice. Hence, typically in South East Asia, low amylose (waxy) types are favoured for some foods as "gelatinous" rice or low amylose rice with a preference for soft textured high-quality rice. Different types of rice have different GI values, ranging from a low of 48 to a high of 92, with an average medium GI of 64 (*19*, *20*). However, this variation remains to be combined with acceptable cooking and organoleptic properties. RS also forms part of the dietary fibre fraction, which in white rice comprises mainly cell wall polysaccharides. DF only accounts for about 0.5–2% of white rice, compared to ~6% in unpolished rice. Although rice grain fibre has not been studied in detail, it is clear that it differs significantly in composition from the well-characterised fibre fractions from other cereals.

Rice DF differs significantly from fibre from wheat and other cereals, comprising ~25% pectin which is only present at trace amounts in other cereals (*21*, *22*). Pectins confer high viscosity to solutions and are thought to contribute to the health benefits of fibre from fruit and vegetables. Indeed, EFSA has accepted a health claim based on the relationship between the consumption of pectins, a reduction of post-prandial glycaemic responses and maintenance of normal blood cholesterol concentration.

Other components of rice fibre are xylans, cellulose and β-glucan (around 25% each).

This is illustrated in Fig. 1. which compares the composition of dietary fibre in white flour from wheat and white rice.

No systematic studies of variation in the content of fibre in white rice have been reported, but studies of white wheat flour have shown variation of up to 2-fold in the content of arabinoxylan (the major fibre component) (*23*). Furthermore, a high proportion (60–70%) of this variation is heritable, and hence amenable for exploitation by plant breeders to develop high DF, healthier rice (*24*). Work in progress in our laboratories is therefore focused on identifying variation in the content and composition of fibre in white rice and combining high fibre genotypes with moderate levels of resistant starch to develop lines combining improved health benefits with good quality and high acceptability.

Disclosure of State of COI

The authors declare no conflict of interest.

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