# Cereal potential

**Grant Campbell**, **Apostolis Koutinas**, **RuoHang Wang**, **Jhuma Sadhukhan** and **Colin Webb** discuss the challenge of engineering cereal-based biorefineries

**CEREALS are the source and the ongoing basis of civilisation. Cultivation of cereals in the Fertile Crescent of the Middle East 10,000 years ago encouraged settlement and allowed population growth which gave rise to cities and hence civilisation.** Today more than half of our global consumption of food comes from cereals, either directly or via animal feed. Global production of cereals exceeds 2b t/y, and each year more than 200m t of cereals is traded internationally, affecting national economies, politics and food security around the globe. Morgan in 1979 noted that "Grain is the only resource in the world that is even more central to modern civilisation than oil". More recently, at the 2004 International Grains Council meeting, Hassan Khedr, Egyptian minister of supply and home trade, also highlighted this underpinning parallel between cereals and oil. He quoted the recent call by the Group of Eight industrialised countries to oil producers, to "produce enough oil to support the world's current rapid economic growth pace" and urged "We, the developing wheat-importing countries, now call on all wheat producers to provide adequate supplies to ensure world wheat prices return to levels consistent with lasting global economic prosperity and stability" (Lyddon, 2004). With current moves to increase usage for non-food products, the pre-eminent place of cereals in modern civilisation is strengthened even further. Socrates' statement that "No man qualifies as a statesman who is entirely ignorant of the problems of wheat" is as true today as it was 2.5 millennia ago.

Cereal agronomy, trading and processing for food uses is global, large scale and highly efficient, underpinning a secure and affordable food supply for much (if unfortunately not all) of the world. Cereal grains are desiccated, making them amenable to long-term storage and efficient transportation and handling, and conferring on them advantages as a concentrated source of diverse functional molecules.

Figure 1 shows the average annual production in recent years of the major crops grown in the UK. Taken together, the cereals provide nearly 22m t/y, more than half of the total crop, with the next contenders being sugar beet and potatoes. However, these two crops are relatively wet when harvested, reducing their functional molecule density and increasing their processing costs. Harvested sugar beet has a sugar content of about 17%, such that on a glucose molecule basis, the cereals produce ten times as much high-value material annually as sugar beet, and similarly, much more than the potato crop. Considering in addition the respective costs of agriculture production, the substantial existing cereals processing infrastructure and the lower costs of dry processing, it becomes clear that currently the most promising basis in the UK for a sustainable chemical industry using renewable raw materials is cereals. Although lignocellulosic materials (wood residues, municipal solid wastes, agricultural residues and dedicated crops) potentially offer cheaper feedstocks, current hydrolysis technology is too energy demanding, expensive and/or environmentally damaging to allow lignocellulosics to compete effectively at this stage.

Despite the clear argument that cereals are the best raw material option for a sustainable chemical industry, at least in the medium term, the current benchmark for economic assessment is oil. In recent years oil costs have increased and cereal production costs decreased, such that the economics are heading in the right direction to favour cereals (Figure 2). In several decades' time oil prices will undoubtedly increase to an extent that cereal processing for non-food uses becomes competitive without specific technological developments or political support systems. However, the non-polluting and sustainability advantages of cereals over oil demand more urgent action to make cereal processing for non-food applications economically attractive as soon as possible.

What, then, are the pieces of the puzzle required to make cereal-derived chemicals competitive with current oil-based equivalents? Four contributing activities immediately emerge: ongoing improvements in cereal agronomy; the chemistry of the extraction and transformation of cereal components; specific process engineering innovations that enhance productivity and/or functionality and/or reduce costs; and integrated cereal processes.

Agronomic practice and productivity affect the raw material cost and hence the overall economics, although issues of plant breeding and husbandry of cereals destined for non-food applications require new thinking in this area. The contribution of chemistry is to address the question: If, instead of starting


## references

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