How has your research background led to your current focus on grain storage?

My research background is in food processing and grain storage. My undergraduate thesis was on dehulling of pigeon peas and my Master’s thesis was on the diffusion of carbon dioxide (CO₂), generated by spoiling grain, through bulk grain. My doctoral thesis dealt with near-ambient air drying of canola.

What are the reasons behind high grain losses and how can these losses be cut?

The main causes of grain loss are high temperatures and moisture contents of grain. At optimum temperatures (27-33°C) stored grain insects multiply faster and cause significant damage. At lower temperatures (less than 10°C) insects do not multiply, and at extreme low and high temperature they are killed. Sometimes average moisture content may be safe for storage but localised pockets of high moisture grain can initiate a hotspot and cause significant loss to a large portion of the grain. Hotspots can be induced by insects or fungi. Also, some species of mould produce secondary metabolites called mycotoxins, which are harmful to animal and human consumers of grain. Mycotoxins can be lethal to consumers when consumed in large quantities – and the effects of consuming low quantities over a long period time could be damaging as well. Thus keeping grain at low temperatures under dry conditions should reduce losses. Also, stored grain must be monitored frequently so that corrective actions can be taken immediately if needed, saving large quantities of grain from spoilage.

Can you explain why a multidisciplinary approach is so important in your area of research?

Stored grain is a humanmade ecosystem where interactions among physical and biological variables cause deterioration of grain. Manipulating the physical environment so that it is not favourable for biological agents is the best way to preserve grains. Therefore, at the very minimum, you need entomologists and mycologists – namely, people who understand the population dynamics of insects and fungi. For example, these experts can test the efficacy of new grain protectants, such as pheromones and microencapsulated insecticides, in field trials. Entomologists may also be able to identify new pests, and mycologists may be able to test the effectiveness of new storage facilities to prevent mycotoxins from developing. It is also important to consider the effects of climate change on stored grain, as it may affect the population dynamics of pests and the selection of mycotoxins. To deal with these challenges, a multidisciplinary approach is necessary.

Feeding the hungry: preservation over production

The grain industry strives to produce, with little regard for preserving what has already been acquired. Research at the University of Manitoba, Canada, shifts the focus onto grain preservation, contributing to a successful and sustainable supply chain.

In a world with a burgeoning population, global food scarcity is an ever-increasing problem. An urgent need for meeting the global demand for food has resulted in the inception of many different strategies for ensuring and improving food availability. A large proportion of these strategies has focused on increasing production. This is especially the case in the grain industry, which produces cereals, pulses and oilseeds for human and domestic animal consumption.

The grain industry has benefited hugely from technological improvements, the use of marginal land for agriculture and the increased use of fertilisers. Grain production has increased significantly as a result of these measures, which in some cases have led to a doubling or tripling of agricultural output. At
also need engineers who have the ability to design systems to manipulate the physical factors of the environment where the grain is being stored and chemists who understand the volatiles produced during spoilage and who are able to design chemical arrays for their detection. Additionally, electrical (nano) engineers are required to design sensors, while economists are necessary for conducting cost-benefit analyses of different approaches to preserve grain. Finally, social scientists are needed for guiding the development of effective policy.

Is it important to avoid a ‘one size fits all’ approach to developing more efficient grain storage in countries around the world? If so, why?

Appropriate technologies and the incorporation of local knowledge and local materials are all critical for building sustainable and functioning systems. Moreover, appropriate training of the people operating the system is also essential.

If one system is simply transposed from one place to another, in many cases this system does not end up being used for long. There are multiple occasions where transposed systems stopped functioning very soon after the donors left.

What do you consider to be the greatest challenges in your research?

Dry grain under low temperatures is a stable commodity so the common perception is that nothing happens to grain during storage – until something goes wrong, that is. This can mean that the contents of the whole bin have to be downgraded, rather than just a fraction of it, or that the grain becomes unfit for human, or even animal, consumption.

Where do you see your research taking you in the future?

I plan to continue working on developing a 3D ecosystem model as a management tool. With weather data from any location, the model will be globally applicable. I will also continue to develop sensors and automated technologies for non-destructive determination of grain quality.

To what extent will greater knowledge mobilisation about preserving grains benefit humankind?

There is a need to mobilise knowledge about preserving grains, enabling it to be used by farmers and storage managers around the globe. Policymakers need to put more emphasis on increased grain availability rather than on increased production. Better preservation of what has already been produced will lead to increased availability of grains to feed a growing world population with safe and nutritious food.
the development of a CAD $5 million facility for studying the processes involved in drying, handling and storing grain. This facility formed the testing ground for the validation of theoretical models devised to explain how heat, moisture and gas transfer through bulk grains, as well as for the optimisation of computer controlled processes and the study of how pests impact on crop preservation and retention. The results of these investigations will provide the tools to guide policy regarding grain production and storage strategies.

The test facility includes pilot- and full-scale modules of all aspects of grain handling and storage. For example, the team uses modules built for near-ambient aeration drying and heated-air drying to test how different temperature, aeration and moisture levels impact on crop spoiling rates. It also uses handling facilities to measure crop loss or damage due to mechanical processes, with the hope of improving these mechanical processes and reducing grain loss. Furthermore, it conducts controlled studies on the effects of insects on crop stores and assess the physical properties of grain in an engineering facility. This allows grain quality to be quantified, as well as new methods for measuring and detecting changes in crop quality to be devised.

As Jayas points out, important factors to take into account include: “temperature, moisture, carbon dioxide (CO₂), oxygen (O₂), grain characteristics, microorganisms, insects, miles, rodents, birds, geographical location and granary structure”. With his colleagues, he has shown that the safe storage of grains can be accomplished through manipulating temperature and moisture content and by eliminating the re-infesting of grain stores. High temperatures and moisture levels cause microorganisms to thrive and grain to spoil, so storage temperatures and moisture tolerance should be carefully controlled depending on the length of time the grain will be stored for. This is something that varies according to the type of grain being stored: “The moisture content for storing wheat safely for up to a year under temperate climatic conditions is 12-13 per cent wet basis, while for storing canola [an oilseed crop], it is 8-9 per cent,” Jayas says.

Jayas has also recently outlined how various spectroscopic methods can be used to measure or deal with different invasive pests, particularly fungi and moulds. This is extremely important for preserving grains and ensuring that they are safe for human and animal consumption.

THE GRAIN-O-BOT

Unfortunately, grain spoiling is not the only factor determining grain loss: significant amounts of grain are also lost due to human error. Recently, Jayas has started to tackle this issue as well, by using cutting-edge technologies to automate various processes in the storage and transport of grains between production sites and destinations. As he explains, this has been a long-neglected part of the grain chain: “Because grain is a low priced commodity, traditionally there has been little automation in its handling and quality monitoring”.

Jayas is working hard to model and identify the processes by which grain is lost or spoilt and, in light of this, to produce automated and efficient ways of reducing or preventing grain loss.
THE CASE FOR PRESERVATION
Reducing the amount of grain lost between farm and consumer would increase the total grain available for consumption. Thus, there are strong arguments for focusing on grain preservation before increasing its production to feed the growing world population:

• **Enhancing quality** – Increasing grain production may increase crop yield but the additional crop may not necessarily be of the highest quality. Thus minimising loss could save a greater amount of high quality grain than increased production would provide.

• **Consumer safety** – The methods used to protect grain also protect the consumer because pests that are harmful to grain – including some types of fungi – can also be harmful to humans.

• **Financial gains** – Saved grains increase income for farmers, reduce the need for importing grains from other countries and can even free up grains for export. This has particularly important implications for nations that currently do not have enough grains to feed their population.

To address this, Jayas has implemented an automated procedure for loading and unloading grain cars with a machine he calls a ‘Grain-o-bot’. This technology uses machine vision to identify sprockets on grain cars to open and close grain car-hopper gates, as well as to identify the contents of grain cars for automating the unloading of grain and its further handling. Opening these gates is an important stage in crop delivery but mistakes are often made because there is usually no opportunity to physically verify the contents of the grain car. This means that if the grain cars get mixed up en route, the wrong grain may be unloaded at the destination, resulting in a loss of grain and large clean-up expenses for the company.

The Grain-o-bot is able to open and close the car-hopper gate extremely quickly, obtaining a small grain sample. It then classifies the contents are correct. In fact, the Grain-o-bot was able to identify Canada Western Red Spring and canola to an accuracy of 99.9 per cent and barley to an accuracy of 100 per cent. It could therefore have dramatic implications for reducing the amount of grain lost due to transportation errors.

**ECOLOGICALLY FRIENDLY GRAIN**
Streamlining grain preservation methods could hugely boost global food security. Indeed, although systematic analysis is lacking, anecdotal reports suggest that in poorly managed storage facilities, some 20-50 per cent of grain is currently lost due to inadequate storage methods. In contrast, well-managed storage facilities lose less than 1 per cent of their crop – so a huge amount of the grain produced globally could be unnecessarily lost due to inadequate storage.

Yet in addition to helping us meet global needs, Jayas’ work could also help minimise collective human impact on the environment. “Through investing in R&D of grain preservation techniques, there is huge potential to reduce the use of fertilisers, fuel and water for per capita availability of grain,” he says. “There is also potential for reducing the amount of land sectioned off for grain production, thus having a positive environmental impact.” As if these gains were not enough in themselves, the economic benefits of improved grain preservation are staggering, with the potential to save US $50 billion dollars annually.

Using optical, thermal, soft X-ray and hyperspectral imaging, Jayas has also been working to detect fungal, insect, sprout and mildew damages in grain. This will lead to the development of devices that can measure changes in grain quality, both on-line and in-line during the handling and processing of grain. Alongside this, he is also eager to continue developing more innovative tools that the grain industry really needs.

STORING GRAINS FOR FOOD SECURITY AND SUSTAINABILITY

**OBJECTIVE**
To discover and develop more effective processes for grain handling and storage.

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