CAPACITY BUILDING

Matie student, Samantha, explores geothermal fish farming at Brandvlei prison complex

This article forms part of a series of profiles on high achieving water researchers supported by the Water Research Commission as part of the Commission's 50-year celebrations.

The Water Wheel paid a visit to Samantha Joao (30), a high-flying researcher with a passion for science, fish farming and teaching. She is among a growing number of former WRC-supported students who are now leading their own research projects. Article by Jorisna Bonthuys.

She is combining her interests in a new project in which she explores geothermal tilapia fish farming at the Brandvlei Correctional Centre. The centre is situated on the bank of the Brandvlei Dam near Worcester in the Western Cape.

Joao is the project leader of a pilot study funded by the Water Research Commission (WRC). Over the next year, researchers will explore the possibility of using geothermal spring water for tilapia (***Oreochromis niloticus***) aquaculture at the centre. This will help promote food security and skills development at the facility, which houses approximately 4 500 people, including prisoners, staff and wardens.

Stellenbosch University's (SU's) Department of Animal Sciences will collaborate with the Brandvlei Correctional Centre, the Department of Environment, Forestry and Fisheries and the Department of Water and Sanitation (DWS) on this project. Joao is working with Dr Khalid Salie on this project. He is a research associate in aquaculture at SU. Joao learned the ropes as his research assistant in 2014 in another WRC-funded project.

In that project, scientists explored technology transfer in the local aquaculture sector. At the time, Joao interviewed fish farmers in the Western Cape, KwaZulu-Natal and Limpopo to inform the findings. She gathered information on the challenges experienced by fish farmers while also exploring possible solutions. "Aquaculture is a real passion for me," Joao says. "It is a

great opportunity to now be working on a new project, with a concept that has never been tested in South Africa before." Joao hopes this project will provide new knowledge on geothermal aquaculture that researchers can apply at other geothermal sites in the country.

Unlocking geothermal potential

A total of 52 thermal springs have been identified as suitable for aquaculture purposes in South Africa. Currently, no fish are grown using thermal spring waters in the country.

According to the Geological Society of South Africa, the Brandvlei hot spring is the hottest and strongest spring in the country. It delivers pure water at approximately 126 litres per second (10.9 million litres per day) at an average water temperature of 64°C.

In 1719, Peter Kolben described the Brandvlei hot spring in a book about the Dutch settlement in the Cape. The farm was officially registered to Petrus de Wet in 1756. The name ***Brandvlei*** (meaning burning vlei) was derived from the steam coming up from the hot spring, which gave the impression that the vlei was on fire.

The spring's water is scalding hot. In the past, locals reported that two children, an ox, a horse, an ostrich and several dogs had perished by falling into the pond at the lowermost spring.

The Brandvlei correctional facility is unique in that all its potable water is sourced directly from the natural, free-flowing hot spring. A portion of the hot spring's water is pumped through mechanical cooling towers, dropping the temperature down to 20°C. The cooled water is then chlorinated and pumped into three storage reservoirs. From the reservoirs, cold water is gravity-reticulated throughout the facility.

Samantha's Master's project focused on chickens.

Excess spring water, which the facility does not use, flows over into a second lower storage pond which DWS manages. This water is pumped into the Brandvlei Dam for domestic and agricultural use.

The advantage of using a thermal spring is that heated water will be available for warm-water (tilapia) aquaculture all year round. Joao explains: "Conventional warm-water aquaculture systems are usually limited to a six-month production period per year. It is just not feasible to artificially heat the water in these systems during the winter months."

The researchers will obtain the necessary permits and permissions, and a small energy-efficient test-system will be set up on-site. "We still need to work out how to introduce the spring water or heat into the test system, as the spring water emerges from the ground at 64°C. Tilapia requires a water temperature of 30°C for optimal husbandry and performance," Joao says.

"We are interested in any potential cost-savings that can be achieved through the use of renewable energy in comparison to a conventional system where artificial heating is used."

The water will be recirculated in the test system, which will probably consist of two portable pools and a filtration system that will be heated using an appropriately developed heat-exchange method. Excess water leaving the system will be filtered to remove organic waste and then returned to the lower storage pond for pumping into the Brandvlei dam later. Fingerlings will be introduced into the pools in the last month or two of the project.

A full growth cycle (approximately six months) will not be possible within this project's timeframe. A co-management plan will, however, ensure continued maintenance of the fish and system until harvest.

Once the test-system is up and running, a workshop will be held to provide training to students and people at the facility. Researchers will cover topics like tank maintenance and cleaning and fish grading procedures at this event.

Chicken or fish?

Since a young age, Joao has been interested in fish. As a schoolgirl, she often spent weekends on her father's small-holding in Somerset West, catching and moving tilapia between dams.

Joao completed her BSc (cum laude) in aquaculture. She then did some travel work as an aquaculture technician at a mussel hatchery in Nelson, New Zealand. She tackled and completed her MSc (cum laude) at SU's Faculty of AgriSciences. Her project investigated alternatives to antibiotics in animal feed for broiler chickens.

Since a young age, Joao has been interested in fish.

Joao originally started her MSc project in aquaculture. But due to unforeseen circumstances and time constraints, she switched to a project with chickens. "I made the most of my situation and embraced the change. If I couldn't do research with fish, chickens were my next best choice. They are such strange but loveable animals.

"Chickens and fish are both monogastric animals, meaning they have a single stomach. Since my MSc project's focus was on monogastric nutrition, the principles that I would learn would be applicable to both fish and chickens. So I adopted that mindset."

While working on her MSc degree, she did some part-time work for Alltech, an animal nutrition company in Stellenbosch. This work entailed gizzard scoring and identifying lesions in the buccal cavity of chickens. "They later offered me a job in product sales, but I declined the opportunity because, at that stage, sales terrified me. I really wanted to get back to the fish and research side of things.

"Then an exciting opportunity opened up at the company's facility in Kentucky, USA. It was exactly what I was looking for and I grabbed the opportunity with both hands."

Joao worked as an aquaculture research scholar for Alltech in Nicholasville for a year. There she gained valuable experience in research with trout, salmon and tilapia in an indoor recirculating aquaculture system. "I followed a rather unconventional pathway in my career," Joao says. "Every opportunity has shaped me differently and I have no regrets."

She is currently a part-time junior lecturer at SU's Department of Genetics, teaching biometry to second-year and postgraduate students.

Aquaculture for the future

Joao says she is excited about this new project. "The potential use of geothermal water sources for aquaculture offers an opportunity to extend the growth periods for warm-water aquaculture," Joao explains. "The thermal spring located at the correctional centre would make a great starting site for a thermal water aquaculture pilot study."

The water is safe to use and also has constant high temperatures and fast flow rates, which would support the culture of warm water fish such as tilapia or catfish all year round. The benefit of a controlled rearing temperature can also increase growth rates by 50% to 100%, which would increase the number of harvests per year.

Global aquaculture production has made significant progress over the past three decades. "It is now the fastest-growing animal-based food-producing sector and has a crucial role to play in reducing pressure on wild fish stocks," she points out.

"In the USA, aquaculture farmers in Idaho, Utah, Oregon and California successfully grow catfish, trout, alligators, and tilapia, as well as tropical fish for pet shops using thermal waters," Joao adds. "And In China, the success of geothermal aquaculture has led to fish farms covering almost 2 million square meters."

Aquaculture can help address the gap between aquatic food demand and supply, she believes. "It can also enable countries to address some of their economic, social and environmental issues," she says.

In South Africa, marine aquaculture has become more popular in recent years. The sector is developing steadily. Freshwater aquaculture is, however, still limited by the availability of sufficient and suitable water.

A major constraint to most freshwater fish culture is the considerable variation in water temperatures between the summer and the winter months. Joao explains: "You get warm and cold-water fish species, so this often limits fish farmers to a half-yearly growth period. which, in most cases, is just enough time to complete one harvest."

Trout farmers have been more successful in selecting sites and optimising their systems to ensure sufficient cold water supplies all year round, she says. However, ensuring a constant supply of warm water that is suitable and inexpensive for optimal warm water aquaculture has proved to be more challenging.

Challenges facing tilapia production have thus limited the local supply, and demand is met through fish imports. However, the market has not been flooded by tilapia imports, Joao says. "There will always be market gaps and opportunities for locally sourced fish products, especially with fresh fish becoming a more sought-after commodity."

Exploring new possibilities

Joao is also enrolling in her PhD this year. "My research will focus on understanding the functional genetic mechanisms underpinning growth across different organ systems in dusty kob. "I have always found marine aquaculture fascinating, as I feel that there are still so many unanswered questions and opportunities to learn and create," she says. "I decided to pursue a PhD in genetics, as I have always found the 'cause and effect' concept fascinating, especially when it relates to the genetic make-up of an animal.

"I feel that cause-and-effect evaluation is a crucial step for fisheries to learn and adapt to changes, which in turn promotes viability and sustainability," she adds.

Dusky kob (***Argyrosomus japonicus***) is a commercially valued fish species that has been severely overfished in recent decades. Due to its large size, palatability, and food value, dusky kob is targeted by recreational and commercial fisheries throughout its natural distribution range. Dusky kob aquaculture is still in its early stages of development, Joao indicates. "With the correct governmental support, it holds promise for the future."

In Southern Africa, dusky kob occurs on the east coast from Cape Point to Mozambique. It is especially abundant between Cape Agulhas and KwaZulu-Natal. In South Africa, its maximum recorded length and weight is 1.75 m and 75 kg, respectively, with a life expectancy of up to 42 years. Dusky kob only becomes sexually mature once they reach approximately one meter in total length, which takes 5 to 8 years.

Although dusky kob can be produced successfully in semi-commercial farming systems, it is not yet feasible for large-scale production locally due to high production costs and relatively low local prices still driven by wild-caught supply. Producers also face the challenge of accessing a high-value export market.

Joao will focus her efforts on the dusky kob's genome (its complete set of genetic information), transcriptome (a collection of all the gene readouts present in a cell) and gut microbiome (the collection of all the microorganisms in its gut). She wants to better understand, from a genetics perspective, why some fish grow faster than others.

"Hopefully, this will help us understand the mechanisms underlying quick growth, which will help improve genetic selection for faster-growing dusky kob in the future," she concludes.

Did you know?

- It is claimed that Chinese people have used hot springs for irrigation since the Jin Dynasty (AD 265-420).
- Over time thermal springs have been used for various agricultural activities, including aquaculture and crop drying. The heat from thermal springs is also used to heat greenhouses and produce vegetables and flowers.
- Thermal springs are by definition 'warm'. Still, there is no consensus on the exact temperature that distinguishes a spring from a thermal spring. Most researchers use normal human body temperature (37°C) as the boundary between 'warm' and 'hot' waters.
- The flow rates of hot springs range from tiny seeps to great gushes of water.
- Source: ***Optimal utilisation of thermal springs in South Africa*** (**WRC Report No. TT 577/13**)

More about the Nile tilapia

- The Nile tilapia (*Oreochromis niloticus*) is fast-growing and considered the most economically viable tilapia species.
- This fish species can live longer than ten years and reach weights exceeding five kilograms.
- Nile tilapia exhibits invasive potential over most of southern Africa that overlap with the natural distribution range of indigenous species such as Mozambique tilapia (Oreochromis Mozambique).
- Nile tilapia is considered an alien invasive species in South Africa. Producers must apply for national and provincial permits for tilapia aquaculture.
- Nile tilapia can be produced in different aquaculture systems, ranging from open ponds fertilised with manure to closed recirculating aquaculture systems.
- Male tilapia grow approximately twice as fast as females.
- Generally, a tilapia stops feeding when the water temperature falls below 17°C.