Tough yet stiff deer antler is materials scientist's dream

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Prized for their impressive antlers, red deer have been caught in the hunters' sights for generations. But a deer's antlers are much more than decorative. They are lethal weapons that stags crash together when duelling. John Currey, from The University of York, UK, has been intrigued by the mechanical properties of bone for over half a century and has become fascinated by the mechanical properties of antler through a long-standing collaboration with Tomas Landete-Castillejos at the Universidad de Castilla-La Mancha.

'Antlers look as if they are dry,' says Currey, 'but no one knew if they really are dry when used in contests'. Curious to find out whether red deer antlers are used wet or dry when duelling, and how this affects the antlers' mechanical properties, Currey headed south to La Mancha to test the mechanical properties of red deer antlers and publishes the discovery that dry antler is stiff and tough on 27 November 2009 in the Journal of Experimental Biology.

But before the team could begin testing the antler's strength, they needed to find out how dry the bones were. Collecting freshly cut antlers from the university farm and a local game estate just after stags had shed the antler's protective velvet, Currey, Landete-Castillejos, José Estevez and their colleagues weighed the antlers each week to find out how much they dried. Amazingly, over the first 2 weeks, the antlers lost a colossal 8% of their weight, compared with 1% weight loss if they were cut at other times of the year. Eventually the weight loss stabilised and the antler's humidity was in balance with that of the surrounding air. It was

clear that the antlers were dry when the stags began duelling.

But how did this water loss affect the bone's material properties in comparison with those of normal bones, which function internally and are always wet? Would the dry antler make a better weapon than wet bone?

The team prepared 40 mm long blocks of dry antler and wet deer femur and measured the amount of force needed to bend the blocks to find out how flexible the materials were. Even though most bones are relatively brittle and inflexible when dry, the team found that the dry antlers are almost as stiff as wet bone: which is ideal for weapons that have to survive a lengthy pushing contest after the initial clash.

But how 'tough' was the antler? How much energy could it absorb in the initial crash? Applying a force to the middle of the blocks of bone and gently increasing it until the bone broke, the team plotted a curve of the bending force against the amount that the bone bent. Calculating the amount of energy that the antler could absorb before shattering, Currey found that the tissue was incredibly tough: 2.4 times tougher than normal wet bone. And when Currey measured the amount of energy that the dry antler could absorb in an impact, he was surprised and pleased to see that it could survive impacts 6 times greater than the impacts that shattered wet femur. The dry antler was tougher than wet bone and ideally suited to survive the stags' initial clash.

So dry deer antlers are simultaneously stiff, yet tough, making them perfectly suited to their role as a weapon. And the deer seem to have solved a problem that has puzzled engineers for decades. 'It is very difficult to make anything that is both stiff and tough,' says Currey, but it seems that duelling deer solved the problem eons ago.

More information: Currey, J. D., Landete-Castillejos, T., Estevez, J.,

Ceacero, F., Olguin, A., Garcia, A. and Gallego, L. (2009). The mechanical properties of red deer antler bone when used in fighting. J. Exp. Biol. 212, 3985-3993. http://jeb.biologists.org

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