High Speed Robotic Y-Cutting of Lamb Carcasses

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Abstract: Previous work by the authors and others has demonstrated successful robotic Y-cutting at process speeds up to 3 carcasses per minute. The development of auxiliary equipment, an improved end-effector, new cutting path and software upgrading of the robot performance has resulted in successful robotic Y-cutting at process speeds up to 8.3 carcasses per minute.

Introduction

This demonstration of the potential of automation for sheep dressing has focused on a single operation - Y-cutting. The Y-cut is one of the first cuts performed after sticking. The cut is from the opened neck, up to and over the hock on both legs. The Y-cut is one of the initial cuts for pelt removal and requires considerable skill to perform manually.

Previous papers have described the development, production and initial trials of the robotic Y-cutting system [Taylor. 1993, Templer et al 1996]. The robot, minus cutting tool, is shown in Figure 1. The complete Y-cutting system includes the robotic manipulator, a specialist cutting end effector, robot controller and control software, remote sensors, end effector steriliser and an opening cutter.

The system was installed for trials in Progressive Meats, Hastings, a small but innovative meat processing plant. The chain at Progressive runs at 2.5-3ccs/min for 16+ hours a day.

Throughout the trial at Progressive Meats the cutting path used for Y-cutting was 'U' shaped. The cutter cut down the leading leg, across the brisket and up the trailing leg. The Y-cut path is shown in Figure 2.

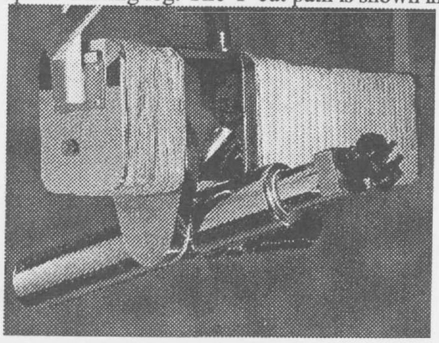

Figure 1. The IRL7L, a four axis cylindrical robot designed for food handling and processing.

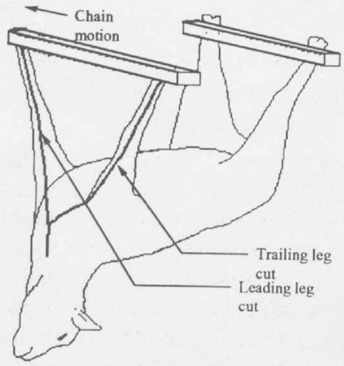

Figure 2. Suspended sheep carcass with the Y-cut path marked.

On Saturday the 16th of December the automated 'Y' cutting system ran for seven and one quarter hours - a full production day. The incision cut was manually performed by hock ringing the right leg prior to the chain transporting the carcass to the robotic Y-cutting system. During the day over one thousand sheep were processed. The total success rate of the robot was **99.1%.** Approximately 1.9% of carcasses failed due to incorrect hock-ringing (too high or low). These failures have not been included in the success rate.

The success rate was extremely pleasing as during the trial day Progressive Meats processed ten different mobs; with wool length ranging from long to snow combed, and sheep including fat lambs, lean meats and new lambs. The next challenge was to operate at large plant chain speeds (8-9ccs/min).

Alliance Smithfield Trials

Alliance Smithfield is a medium sized meat processing plant situated in Timaru in the South Island of New Zealand. The plant has two sheep processing chains and processes up to 3000 sheep per chain per day. During the trial the robotic system was installed, tested and improved. Two MAF supervised microbiological trials were conducted.

Smithfield Improvements

Major improvements between the installation in Alliance Smithfield and Progressive Meats included:

Chain Speed. At Progressive the robotic Y-cutting system had 20 seconds to cut and sterilise at Smithfield it had 7 seconds. This three fold reduction in time available meant greatly increased cutting speeds, which in turn lead to much higher loads. In practise the cutting speeds required to complete the Y-cut for every sheep were 5-6 times that used at Progressive.

Merino sheep requiring a new cut pattern. Merino and Merino Cross breed sheep store fat in large rolls around their necks. This results in large folds of skin and wool. Despite many changes to the cutting tool and robot's path, these folds made a 'U' cut path unworkable. Thus the chosen cut path was: Steriliser - Cut down leading leg - Up to top - Cut down trailing leg - Up to top - Steriliser. This is shown in Figure 3.

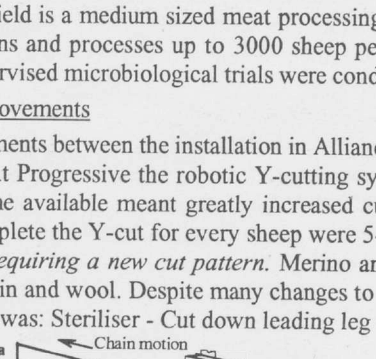

Figure 3. Robotic Y-cutting system cutting path. Note: the actual path describes a different shape due to the motion of the chain..

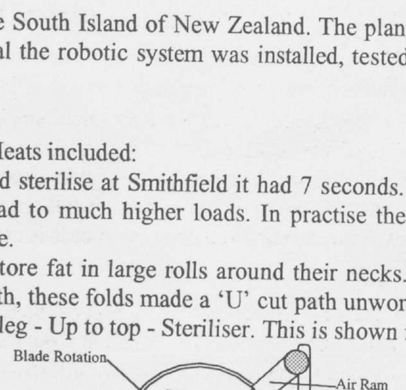

Figure 4. Automatic opening cutter plan view schematic. The cut is caused by the serrated blade cutting through the pelt at the tangential point of contact. The cut is on both legs 25mm above the hock.

Automatic Opening Cutter. This was designed, built, developed and trialed on site. The final unit uses an electric motor to drive a 400mm diameter serrated circular saw blade. The blade is forced against the legs by an air-cylinder and hinge system, as shown in Figure 4. This occurs upstream of the Y-cutting and creates a horizontal insertion cut above the hock on both legs. Shown in Figure 4.

Moveable Steriliser. To remove the risk of collision with the steriliser and to give the robotic Y-cutting system the maximum range within its working envelope, the steriliser was programmed to swing clear of the work space when the cutting tool was not inside it. This was achieved by a solenoid controlled air cylinder on a hinge mounting.

Air Jets. These were mounted on the tool and aimed at the blades. Following completion of the cut down each leg, the jets would be turned on and successfully removed wool from the blades. This solved a major problem of wool ingress into the tool.

Winged Keeled Blades: Blades modified to increase clearing were used, developed and improved throughout the trial. The increased clearing or flaying blades gave excellent results. The blades consistently cleared 20-25mm either side of the cut allowing further processors to easily grip the pelt. An important modification of the initial 'winged' design was to use (ll) shaped 'wings'. These reduced the risk of pulling though the pelt and reduced the amount of wool snagged by the tool on exit.

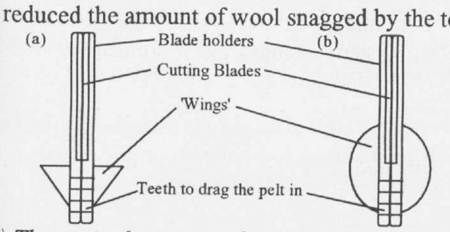

Figure 5. (a) The orginal wings on the cutting tool. These tended to trap wool on the back (top) edge. (b) The redesigned wings allowed the wool to slide off.

Total Trial Time:	3.5 hours
ChainSpeed:	8.3 ccs/min
Total Sheep:	1750
Success Rates :	98.2% Leading Leg 95.1% Trailing Leg

Figure 6. Trial Results Table

Trial Results

After many days of developmental trialing the robotic Y-cutting system was used for a sustained period. The operating conditions were: fully automatic, double down cut and sterilise. The Sheep were from numerous mobs, mixed lambs and ewes. The results are summarised in ig.e 6.

Reasons for Failure: Bent blades (1.0%), Incorrect insertion cut (0.5%), Leg out of spreader (0.3%).

The cutting system was fully automatic and required no human assistance or intervention. The robotic Y-cutting system performed Y-cuts at full chain speed, starting above the hock for both legs and cutting diagonally down to leave a generous flap. The cutting tool was sterilised between each sheep. An eight hour trial was not possible due to the end of the killing season.

Y-cut failures were primarily caused by bent cutting blades. Other causes were incomplete opening cuts and legs coming out of the spreaders prior to Y-cutting. The cutting blades bent because of under-design. The blades and tool were designed to withstand the forces of 3ccs/min processing. At Alliance Smithfield they were subjected to greater than five times those forces. In some cases the opening cutter did not cut fully around the rear leg, resulting in missed insertion. This can be corrected by increasing the inwards pressure.

A rare cause of failure was the leg not being in the spreader. The robotic Y-cutting system currently lacks the sensors to detect this and cannot correct the situation. This problem cannot be overcome other than by encouraging up-chain workers to ensure that they have done their jobs.

MAF Microbiological Results

Because of commercial sensitivity the microbiological results cannot be detailed. However the log of the aerobic plate count for the 50 carcasses trialed was approximately 10% lower for the robotic Y-cut carcasses compared with the manually Y-cut carcasses. The log E. Coli count was similar. In a MAF communication it was stated 'It is concluded that the robotic Y-cutter performs at least as well, and somewhat better than, manual Y-cutting in microbiological terms, with the added advantage of highly repetitive, consistent removal of wool accumulations from the cutting blade'. It is also likely that most of the contamination found on the stock cut by the robotic system was due to the further processing (shoulder pulling etc) carried out prior to samples being taken, and the manual handling necessary to transport the sheep to a stationary line for testing.

Conclusions

The robotic Y-cutting system is ready for commercialisation. The next trial of robotic Y-cutting will be with a commercial version of the robot, cutting tool and auxiliary systems. This conclusion is based on the fact that all parts of the system work. No further research work is required to solve problems relating to Y-cutting. The system described here is a prototype. Subsequent work will focus on delivering the robustness and durability required for a system that will be in full time use. The 'winged' blades work and will be used on the commercial systems. MAF process approval has been obtained and the process is cleaner than manual Y-cutting.

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