final report

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Alternative Meat Shaping Technology Design

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Contents

The project aimed to develop a professionally designed alternative technology for shaping irregular primals and sub-primals in order to increase their value by improving their plate profile. A peristaltic shaping device has been developed by MLA and MWNZ, but commercialisation has proven difficult due to low throughput, labour intensity and perceived high initial capital cost. This project will develop an alternative non-peristaltic technology.

Objectives

The objective is to create a machine concept that, ultimately, could
1. Stretch a meat cut by 15% to 20% longitudinally, and
2. Load that stretched shape in a food-grade, disposable, low-cost retainer (such as a plastic tube)
3. Preferably circular in section but could be rectangular.
4. Complete this operation in say 5 to 10 seconds
5. Is low cost to buy, and easy and low-cost to operate.

Concept Background

The **Funnel Conveyor** concept aims to achieve this by deploying 4x belt conveyors to form the 4x sides of a tapering, square sectioned funnel, such that the synchronised motion of the 4x belts will drag in the meat cut as well as to compress it (due to the diminishing cross-sectional area as the meat cut progresses down the funnel), thereby achieving the stretch by squeezing. Furthermore, real stretching can be achieved by a second set of similarly deployed conveyors, but forming a gentler funnel angle, and moving at a higher differential speed relative to the first set of funnels.

At the exit of the second set of funnels, the meat will be extruded into a smooth metal funnel whose cross-section transforms from square to round. Onto this metal funnel will be applied a plastic tube into which the meat will be extruded for retaining its shape.

The benefits of such a machine concept, if successful, are:
1. Very high speed operation. A 500mm long meat cut can be transformed in say 2 to 3 seconds.
2. Linear through-flow for ease of operation ie in one end and out the other.
3. Easily adjustable compression by changing the funnel angle of each belt conveyor to adjust the relative infeed to exit cross-sectional area ratio.
4. The possibility to dynamically vary and match the funnelling ratio to different incoming meat cut sizes.
5. Potentially low cost to build and operate.

The uncertainties are:
1. Whether or not meat will extrude out between the gaps between each pair of belt conveyors. Although the belt can be touching as they all move at a synchronised speed.
2. Whether or not the meat will tear or slip or be otherwise damaged. However, functional severeness can be minimised by using longer belt conveyors, for example, if a limiting maximum funnel angle is found (that either slips or damages the meat or promotes extrusion between the belts).)

3. In the 2 stage funnel option, whether or not the meat will snag or lose its compressed shape during the transition between the 2 funnels.
4. Whether or not the conveyor belt extruded meat cut can be fed into a plastic retainer tube.

1. Milestone 1 Conclusions

Main results of the First Stage were that

1. Meat cut shaping is feasible using the funnelling conveyor concept.
2. It is fast.
3. The meat cut retains its shape for a short time after shaping.

In a Stage 2 work, we proposed additional tests to:

1. Explore whether or not a higher degree of funnelling is achievable with the set of higher grip conveyor belts (on order). If this is positive, we will
2. Expand the Test Rig to test the Secondary Stretching Funnel idea, that is by using another 4x Ryobi belt sanders to form a second funnel following the first set.
3. After that we will try over stretching the meat cut, to test the viability for loose insertion of the meat cut into a plastic tube.

2. Milestone 2: Objectives

The objective of Stage 2, is to carry out the remaining tests and to gather sufficient design data to confirm the viability and practicability of a machine concept that, ultimately, could

1. Stretch a meat cut using the 2-stage funnelling conveyors, and
2. At the exit of the second funnel, load that over stretched meat cut into a plastic tube freely.
3. Expand to fill the plastic tube after unloading off the machine.
4. To carry out this operation in say 5 to 10 seconds

3. The 2-Stage Funnelling Conveyors Test Rig

The 2-Stage Funnels Rig is based upon the addition of a second set of funnelling conveyors below the initial set. It is shown in Figs 1, 2, 3 & 4.

Fig 1 shows the overall view of the 2-Stage Funnels Test Rig. In this a replica set of 4x Ryobi belt sanders were installed to receive the meat cut exiting the first set of funnels. A rigid frame that allowed the setting of the belt angles and re-sizing of the entry and exit sectional areas, tied the funnels together. Enough space was allowed for the exit of the stretched meat cut below the second set of funnels.

Fig 1: Overall view of 2-Stage Funnels Test Rig

Fig 2 shows a close up view of the transition between the first set of funnels and the second set of funnels. This gap is around 20mm.

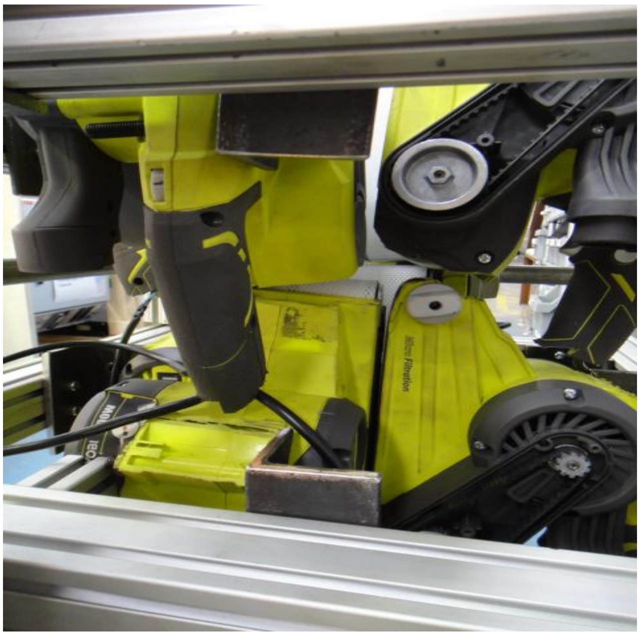

Fig 2: Close-up view of the gap between the first and second sets of funnels.

Fig 3: View showing the entry into the first set of funnels.

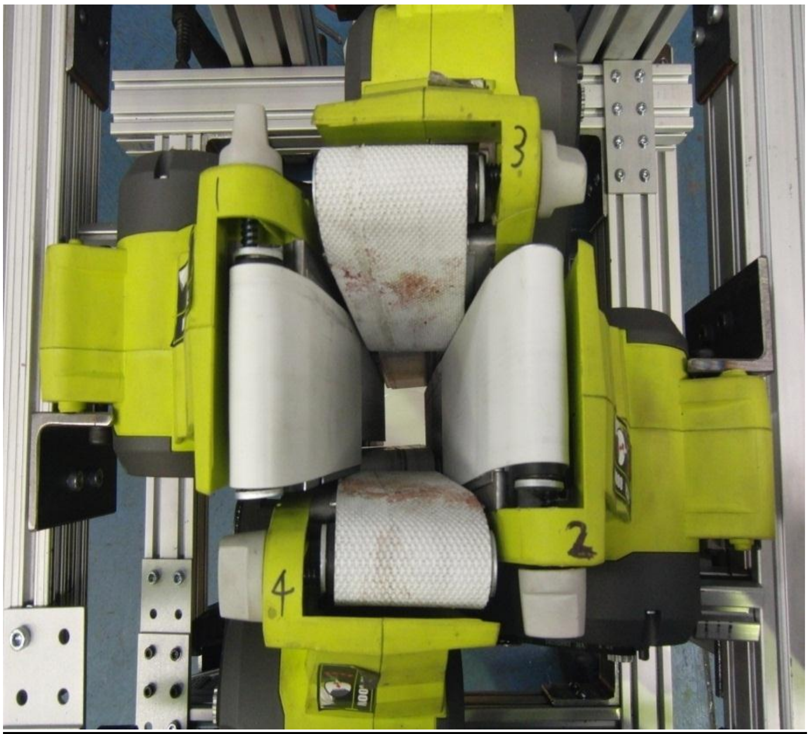

Figure 4: Top view of funnel set-up. The smaller exit aperture of the second funnel set is visible.

In addition, 2 types of the FDA approved conveyor belt surfaces were tested. The types of belts used comprised a grooved PVC flat belts and a smooth polyester flat belts (Figure 5).

Each stage consists of 2 grooved and 2 smooth belts running opposite of each other as shown in Figure 4. There was not a significant difference in traction between the two types of belting.

Figure 5: Belt surface types

In setting up the this Test rig, no specific angle of tilt was used on the sanders but they were adjusted so as to achieve a Stage 1 entry and exit area of 80x80mm² and 60x60mm² respectively, and Stage 2 entry and exit area was slightly smaller at 70x70mm² and 50x50mm², respectively also.

The relevant hardware parameters at set up are described below.

Sander Specifications

Model	Ryobi EBS800V
Rating	800W
Voltage	240V ~ 50Hz
No-Load Speed (Speed 1-6)	150 ±15% m/min – 330 ±10% m/min
Sanding Area Size	76 x 150 mm^2
Sanding Belt Size	76 x 533 mm

No-Load Speed Measurement

Measurements of the surface speeds of each individual belt sander were performed using a Digital Photo/Contact Tachometer (RS 13-5348).

Figure 6: Tachometer

Sander	Speed Setting	Belt Type	m/min	m/sec
1st Stage				
1	1	Smooth	181.3	3.02
2	1	Smooth	174.9	2.92
3	1	Grooved	162.1	2.70
4	1	Grooved	160.9	2.68
2nd Stage				
1	2	Grooved	201.7	3.36
2	2	Grooved	195.0	3.25
3	2	Smooth	184.3	3.07
4	2	Smooth	188.7	3.15

Note the speed differential between the average speed of the first set of funnels and the seconds set of funnels.

4. 2-Stage Funnel Test Results

Using the Test Rig in the set-up as described above, with respect to the funnelling angles and the differential speeds between the two sets of funnels, we carried out repeated tests with 3 pieces of meat cut over the course of one morning.

The primary findings were:

1. the compressed meat cut transitioned between the first set of funnels into the second set of funnel without a problem of meat extrusion or “leakage”, as expected. If required, the transition gap between the two sets of funnels could be greater than the 20mm tested in the Rig.

2. The temporary plasticity of the meat cuts was again evident after the meat cut’s exit out of the second funnel set.

Figs 7 & 8 show the Meat Test Piece 1, before and after stretching through the Test Rig. It can be seen that the original length at 250mm was stretched to over 300mm, and the about 130mm height before stretching was reduced about 100mm.

Fig 7: Meat Test Piece 1: Before Stretching

Fig 8: Meat Test Piece 1: After Stretching

Figs 9 & 10 show the Meat Test Piece 2, before and after stretching through the Test Rig. It can be seen that the original length at 220mm was stretched to over 260mm, and the about 130mm height before stretching was reduced about 90mm.

Fig 9: Meat Test Piece 2 Before Stretching

Fig 10: Meat Test Piece 2 After Stretching

Figs 11 & 12 show the Meat Test Piece 3, before and after stretching through the Test Rig. It can be seen that the original length at 230mm was stretched to over 300mm, and the about 120mm height before stretching was reduced about 90mm.

Fig 11: Meat Test Piece 3 Before Stretching

Fig 12: Meat Test Piece 3 After Stretching

We have claimed to observe a temporary plasticity in the meat cuts after the meat cut's exit out of the second funnel set, and that its reversion back to near its original dimension occurs over a period of minutes.

Quantitative data on this phenomenon is now necessary, in order to determine:

1. the time the meat cut has to spend in the second set of funnel – which is a function of funnel conveyor belt length and conveyor belt speed.
2. for the feasibility of the loose insertion of the stretched meat cut freely into a plastic tube, the meat cut's shape recovery must be slow.

Tests to quantify these parameters is the objective of another set of test below.

5. Meat Cut's Plasticity Measurements

In the next set of tests, we will measure the meat cut's **rate of shape recovery**, and to test how this might be dependent of the **magnitude of compression** and the **time** for which it is held under this compression.

For this test, we built a Static Compression Test Rig, as shown in Figs 13, 14, 15 & 16.

Fig 13: Static Compression Test - Meat Trough and Limit Blocks.

Fig 13 shows the meat cut support trough and at each end the limit blocks that sets the height that the meat cut can be compressed down to. Fig 14 below shows the meat cut being loaded into the trough.

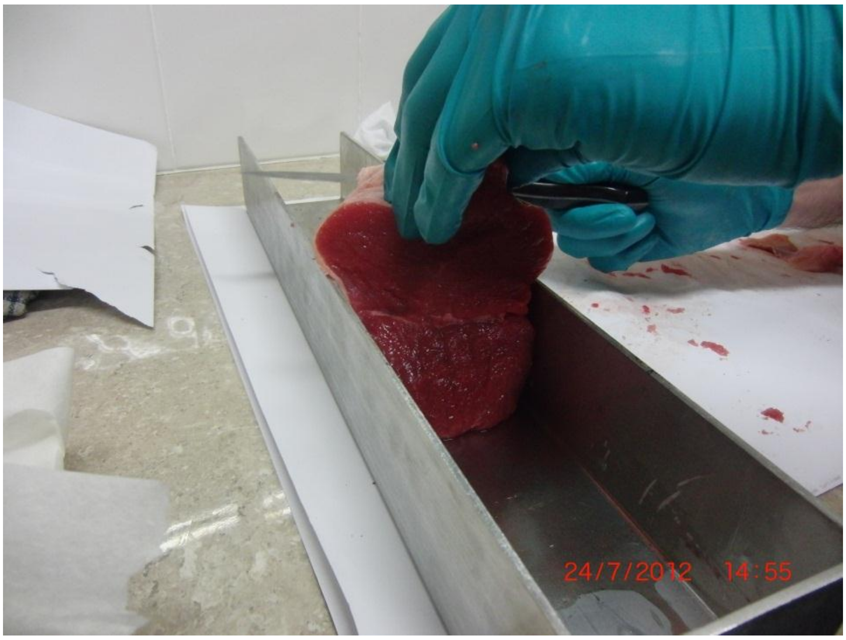

Fig 14: Static Compression Test - Meat Loading into Trough.

Fig 15 shows the meat cut being compressed between a loose fitting 'lid' and the trough. The limit blocks have been removed in this view for clarity. Fig 16 shows a variety of limit blocks.

Fig 15: Static Compression Test - Meat Clamped.

Fig 16: Static Compression Test - various Limit Blocks.

Basically, in this test we compress a particular meat cut to a fixed compression (re limit blocks) and clamp and held it for various time intervals ranging through 2sec, 5sec, 10sec, 20sec, 40sec, 60sec and 120 seconds.

For each of these clamped time intervals, we unclamped and measured the height of the freed meat cut at 5 seconds interval up to 240 seconds.

The general result was that the meat cut remained at very near its clamped height for between 5 second and 20 seconds after first being freed, this is dependent on 2 variables

a. On the severity of the compression and
b. The time interval for which we clamped it

then slowly it reverted back to near its original height.

These results are shown in a spreadsheet in Table 1: Static Compression Tests.

For example, take Meat piece No.2.
Its original height of 45mm was compressed down to 34mm.

- If the clamp was held for only 2 seconds, its freed height is 42/43mm for the first 15 seconds post-clamping.
- If the clamp was held for only 10 seconds, its freed height is 39/40mm for the first 35 seconds post-clamping.
- If the clamp was held for only 20 seconds, its freed height is 37/4383mm for the first 30 seconds post-clamping.

Another example, take Meat piece No.3.
Its original height of 60mm was compressed down to 39mm.

- If the clamp was held for only 2 seconds, its freed height is 46/48mm for the first 5 seconds post-clamping.
- If the clamp was held for only 10 seconds, its freed height is 42/43mm for the

first 25 seconds post-clamping.
- If the clamp was held for only 20 seconds, its freed height is 41/43mm for the first 45 seconds post-clamping.

The conclusion is that the longer and more we compress a meat cut, the more slowly is its rate of recovery. Final recovery after several minutes is around 90%.

6. Prototype Parameters

Let us look at the implications of the above data for a practical prototype machine.

Let's say that a stretched meat cut is 500mm long. At a slow post compression recovery rate, if in the initial 5 seconds the recovery is a few millimetres in diameter, then the meat cut can travel at 100mm/sec to be fully inserted into the 500mm long plastic tube in the 5 seconds. It needs to be "over-stretched", that is to be smaller than the plastic tube by say 20mm in diameter, for the meat cut to insert freely over the entire 500mm length of the tube.

Let's look at the other implications of the 100mm/sec tube insertion speed. In order for low recovery rate of a few millimetre over 5 seconds to be realised, we have to hold the meat cut in compression for at least 10 seconds at the upstream stage, ie when in the second set of funnels.

At this same speed of 100mm/sec through second set of funnels, the funnel length needs to be at least 1m for a clamp time of 10 seconds. This is a practical length.

Alternately, if the travel speed through the system is lowered to 50mm/sec, a second funnel clamp duration of 10 seconds is achieved with a conveyor length of only 500mm, but the "threading" time through the 500mm long plastic tube becomes 10 seconds – this is still acceptable, and we have a shorter machine.

7. Conclusions

The above illustrates that these test results points to the conceptual feasible of the **Twin Funnel Compression Conveyors with Free Insertion into the final Product Tube**. Also, quantitative tests and data have established the practicability of the concept for a production machine.

We suggest that a vertical arrangement of the twin funnels with an inclined raw meat cuts infeed conveyor. Under the second funnel set can be positioned the plastic tube making/loading module. The next step is to see how this twin Funnel Meat Shaper can be meshed with your current work on a high-speed plastic tube making/loading machine.