Snapshot Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

Water Holding Capacity & NMR (Preliminary Study)

Full Project Title

Project Code	Prepared by	Date Submitted
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Project Description

This work is ascertains whether Nuclear Magnetic Resonance (NMR) can be used to make measurements and/or predict attributes related to water holding capacity of meat. WHC is a descriptor of extremes in meat quality and NMR is an excellent tool for measuring not only total water but also attributes of that water eg the location or water populations in the meat.

This project reviews the literature to ascertain opportunities to extend the potential value of (NMR) measurements for objectively characterising meat eating quality traits and also for improving meat processing practices. An NMR tool for use in the meat industry is under development.

Project Content

Meat is more than 70% water by weight. Water is both a critical component of eating quality and an important contributor to weight-based of carcase value.

Water holding capacity (WHC) is the ability of food to hold its own or added water during the application of force, pressure, centrifugation or heating. This includes during the processes of fabrication, processing and storage.

For consumers, poor WHC can result in excess drip/purge in retail packages and inferior visible appearance, tenderness and juiciness (Pearce et al., 2011). For processors, drip loss (as distinct from evaporative losses) is a matter that requires attention; any fluid losses are weight losses that impact weight-based value.

For processors, extremes of WHC include DFD meat which has WHC and PSE meat which has low WHC. DFD and PSE meat has a cost to the meat industry and is to be avoided. DFD meat is **d**ark, **f**irm with a **d**ry appearance. The dry appearance is believed to be the result of unusually high WHC. PSE meat is pale, soft and exudative and results from a rapid post-mortem pH decline while the muscle temperature is too high. The low pH and high temperature adversely affects muscle proteins, reducing the ability of the protein to hold water.

Existing methods of measuring WHC either gauge natural release of fluids from muscle or require the application of force to express water and are gravimetric or centrifugal (Oswell et al, 2021, de Almedia et al, 2017), including Bag Method, EZ-Driploss and Filter paper wetness method. All of these methods are time consuming, require meat samples and most take 24 to 48 hrs to provide results.

Leading European meat researchers, where the focus is on chicken and pork, suggest that rapid or predictive methods for detecting drip loss will be spectroscopic (Feedchannel). This was backed up by papers in the literature.

The main body of research in-plant are infrared (IR) studies. The studies showed strong correlations for IR spectra to predict drip loss. For example:

- In 2000 Forrest reported on Near Infrared (NIR) studies on a slaughter-line with the objective of predicting drip at 24hr. In a study of 99 pigs, NIR measurements through a fibre optic probe and starting only 30mins post exsanguination showed a high correlation (r=0.8) with drip loss at 24 hours (Forrest et al, 2000).
- In 2001 Morgan studied 120 pigs[1], collecting data on changes in temperature and pH between 0 and 24 hrs post mortem. Using a fibre optic near reflectance probe inserted into the muscle, spectra were recorded for 6mins at 30 mins post mortem. The correlation coefficients showed that both pH and temperature are

[1] Note - pigs are scalded at 7 mins post-mortem and processed according to normal slaughter procedures. This is noted as it is a key difference to beef or lamb processing.

correlated with drip loss as early as 7 minutes after exsanguination (r=0.7). There was also a strong correlation between drip loss and pH (r=0.78).

- In 2003, in further pork studies, Pedersen conducted preliminary studies at a research slaughterhouse and revealed a high correlation between WHC and both IR (r=0.89) and Raman spectra using Partial Least Squares Regressions (PLSR). The results were confirmed under industrial conditions using FT-IR at-line spectroscopy. However, the latter experiment yielded a somewhat lower correlation (r=0.79).
- Then most recently in 2017, Vautier et al, tested a dedicated industrial in-line device that uses NIR (NitFom, Frontmatec) for its ability to predict drip loss and ultimate pH (pHu); most of the NIR spectrometers available are not suited for on line measurements in slaughterhouses. They showed a calibration model fitting was satisfactory (drip loss, R^2=0.59 and pHu, R^2=0.70).

There were more relevant studies in the literature using infrared than NMR. The NMR studies showed the same trends although the studies using NMR are less applied (i.e. work was limited to the use of laboratory equipment). The following are some key findings from NMR studies:

- Equivalent studies using NMR (but not on the slaughter floor) showed strong correlations with drip loss (r=0.75) across and extreme range of drip loss of pork (Bertram H.C et al., 2001; Brøndum et al., 2000), and in
- In 2000, Brøndum compared the ability of different spectroscopic methods for predicting WHC (four spectroscopic instruments, a fibre optical probe (FOP), a visual (VIS) and near infrared (NIR) reflectance spectrophotometer, a reflectance spectrofluorometer and a low-field 1H nuclear magnetic resonance (LF-NMR) instrument). In studies of 39 pigs WHC (drip loss and filter paper wetness) and chemical composition (intramuscular fat and water) were used for reference calibrations. Findings included the best regression models were obtained from low field NMR (correlation coefficient of 0.75 with drip loss).
- Time Domain or Low Field NMR studies have been used to model and characterise water movement. Pearce et al., 2011[2] proposed models for water processes that occur as muscle turns to meat post slaughter and other have used NMR to test the models:
  - Kristensen and Purslow (2001) showed water flowing out of the cell during rigor when the muscle fibres contract and then begins to flow back in as the protein structure degrades and relaxes. They made their first measurements at 24 hours post mortem and missed the initial swelling of the fibres due to increased ionic strength inside the cell related to the slaughter conditions.
  - Bertram et al. show how the NMR parameters T_{21}, p_{21}, and T_{22}[3], follow this water movement trend. Post mortem, water migrates into the myofibrils, the fibre swells. The larger volume decreases the water's interaction with the protein. This decrease surface to volume ratio is observed as a longer T_{21} and the increased volume results in increased p_{21} and decreased p_{22}. The extra cellular water is

[2] After a period of swelling, the water migrates out of the intra-myofibrillar space to an extra-myofibrillar space before degradation of the membrane occurs and the water is able to exit the muscle fibre completely through channels between the muscle cells (Pearce et al., 2011)

[3] Where T_{21} and T_{22} are transverse relaxation time constants and p_{21} and p_{22} are the fluid population.

observed as increases in p_{22}, however, during the first 24 hours the water is closely associated with the myofibrils.

Project Outcome

A review of the literature with respect to measuring and predicting WHC has shown:

- The studies we found were of pork and rabbit
- NMR studies of WHC are not extensive and they are laboratory based
- The NMR studies showed that T_{21} and T_{22} correlate strongly (r=0.7) with drip loss at 24 hrs and track pH induced structural changes; so drip loss at 24hrs can be predicted
- NMR data beyond 24hrs, for predicting purge in packaging, did not show a good correlation, so
- Further, NMR was shown to be able to follow the water movement trends

There were some limitations to the NMR work, e.g. the studies used laboratory equipment and the samples were models. Therefore, if we only considered the findings of the NMR data then one might question the appropriateness of expecting to gain the same results in an abattoir. In this regard, the IR data was important in that it presented the same correlations using in-plant studies.

While the IR results look promising, IR models have limited lifetimes and require maintenance that compensate for changes in many variables ranging from season, feed, instrument, etc. All the publications cited in this report show one study, at one time, and with one model. The high variability in meat suggests that these models will need frequent recalibration (Mercader, M.B and Puigdomenech, A.R, 2014). Also, in-plant IR measurement times were reported to take 6 minutes.

A question that needs consideration is whether the predictions would hold for beef and lamb. It seems reasonable to assume that if the processes and mechanisms of WHC are the same as pork then there is no reason why not. Further work is required to confirm this. This work would be best conducted using NMR as it is direct, calibration is simple and measurement times consistent with line speeds are possible. However, at this time, NMR equipment for applications to meat in a processing plant are still in development (McCarney, E. and Webster B, 2021a&b)

Benefit for Industry

The literature suggests that NMR measurements of WHC or proxies could provide the following benefits:

Predicting Drip Loss – drip loss could be predicted through measurement on the slaughter floor and predict drip loss at 24hrs. As payment schedules include consideration of carcase weight, this could be valuable to producers and processors, separate to using measurements to consider quality. This measurement could be taken on the slaughter floor soon after post-mortem (possibly less than an hour post mortem).

Sorting into the Chiller - The greatest benefit would be for sorting into the chiller based on a prediction of drip loss. Drip loss prediction could possibly be used to sort carcases with an increased likelihood of PSE and DFD meat (as these have noticeably distinct WHC), allowing targeted early intervention with tool such as electrical stimulus. In 2014 DFD meat in the Australian beef industry was estimated at 10% with an estimated cost of $36M through downgrading (MLA, 2011).

DFD Prediction – the NMR parameter T_{21} has an opposite trend than standard meat suggesting that NMR could be used to predict dark cutting meat measured between 1 and 12 hours, with the differentiation dropping off after 24 hours (Bertram et al., 2003)

pH complementary measurements - The literature suggests information provided by NMR in the first 24 hours would be complementary to pH measurements, tracking the pH induced structural changes post mortem. This opens the door on the potential for alternate measurement to pH; measurement that could be automated and non-destructive.

Based on the correlations noted in literature we also believe NMR could be used to confirm optimal ageing progression (with measurements at different times) and other literature showed that NMR could assist with measuring purge in vacuum packed bags (Zhu, H. 2017).

Useful resources

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