Project overview

On-Pack visual indicator to check freshness and quality of raw beef

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Brief summary

The aim of this PhD project (as part of the Monash GRIPs cohort) was to develop an on-pack visual sensor for raw beef that will provide information both about the eating quality and freshness of the product, leading to cost savings, wastage reduction, enhanced sustainability, and ultimately better service to the industry and consumers. Many of the existing food spoilage sensors are not commonly used as they are either too expensive (comprising up to a quarter of the total packaging cost) or difficult to interpret, requiring apps or non-visual devices to translate the sensor output to a visual cue for the consumer. Lack of proper information about the condition of packaged meat might lead consumers either to discard meat that is still fit for consumption, at an obvious economic and environmental cost, or to eat food that is no longer safe. A cost effective, food safe and biocompatible visual on-pack sensor, to monitor the packaging environment and state of the packed product, and that visually indicates information directly to the consumer to help in their decision-making process is highly desirable. In this project, we have developed an on-pack visual indicator prototype for packaged red meat. We first identified the volatile compounds released from porterhouse beef steaks in three different commercial packaging systems before and after the best before date, and then extended the analysis procedure to non-invasive sampling of volatiles from the headspace of MAP packaged beef. The absence or presence of these volatiles is related to the meat quality and freshness, and knowledge could be used for sensor development. We have applied several natural and synthetic dye-based sensors for the detection of these volatile compounds, and their colour change is indicative of the degree of spoilage of the packaged meat. Finally, we tested a combination of three sensors *in situ* on simulated commercial packaging to verify the sensor response relative to the commercial best before date. Our on-pack meat quality and freshness sensors are scientifically proven and industry ready for implementation.

Objectives

1. To identify volatile compounds from raw beef packaged in three different commercial packaging systems.
2. To correlate these volatile compounds with meat quality and freshness.
3. To identify pH sensitive dyes that can detect the volatile compounds related to packaged raw beef quality and freshness.
4. To develop an on-pack dye-based sensor as a visual indicator of packaged raw beef quality and freshness.

Project outcomes

Outcome 1: Design led survey of the sensor prototype

- In order to understand the consumer perspective of the on-pack sensor; market research was conducted by Monash Food Innovation (MFI).
- 500 consumers were approached with a questionnaire and the prototype of our on-pack sensor (**Figures 1 & 2**).
- The idea of an on-pack visual indicator was well received by consumers and majority of them showed interest in the uniqueness of the idea and were likely to buy the red meat with the on-pack indicator.

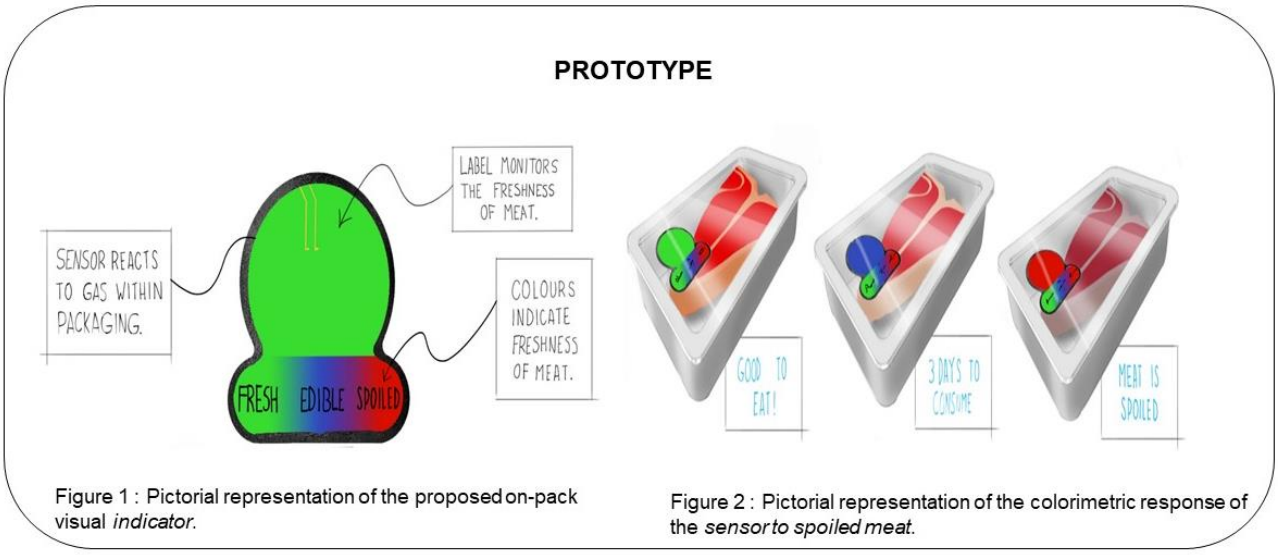


Figure 1 : Pictorial representation of the proposed on-pack visual *indicator.*

Figure 2 : Pictorial representation of the colorimetric response of the *sensor to spoiled meat.*

Outcome 2: Identification of volatile compounds released from beef from different packaging systems

The volatile profiles of raw beef steak initially packaged in modified atmosphere packaging (MAP), vacuum packaging (VP) and cling overwrap packaging (CP) were determined over a 7-day period. 36 volatile compounds were identified across the three packaging systems. the results indicate that the packaging system and conditions, as well as storage conditions, play an important role in the release profile of volatile compounds from raw beef. This qualitative study contributes to the knowledge about the compounds released from raw meat under typical packaging and storage conditions. The demonstrated relationships between packaging systems, volatile compounds and storage times have potential application in the development of on-pack freshness and quality sensors.

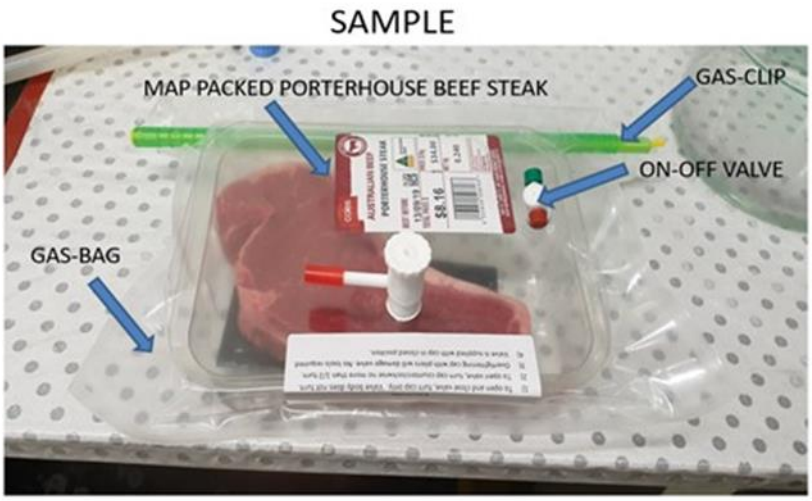
A manuscript of this chapter is under preparation for submission to *MDPI Foods*.

Outcome 3: Identification of volatile compounds released *in situ* from beef in commercial Modified Atmosphere Packaging (MAP)

This study presents and validates a non-invasive extraction method to identify volatile compounds in the headspace of Modified Atmosphere Packaging (MAP) beef steaks during its spoilage when stored at 4 °C and 20 ˚C for 1 week (**Figure 3a & 3b**). This extraction method will reduce the error margin of volatile identification from MAP and the information obtained could be used as a parameter to determine the quality and freshness of MAP packaged raw beef. Although the meat spoilage reaction pathways were not investigated in this study, detected compounds that are known to result from biological reactions, including acetoin, carbon disulfide, dimethyl disulfide, hexanal, 2,3-butanedione, were identified as potential spoilage markers of raw beef under MAP conditions. These compounds have been identified as potential target analytes for developing an on-pack freshness and quality sensors.

A manuscript of this chapter is under preparation for submission to *ACS Journal of Agriculture and Food Chemistry*.

(a)



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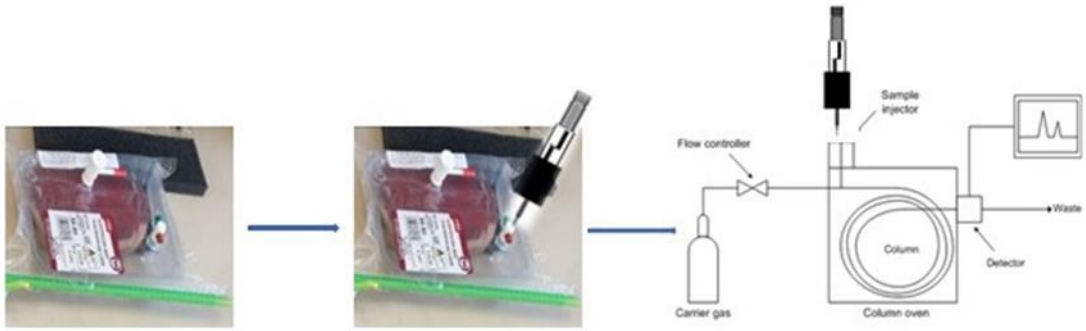

Figure 3: Experimental setup and sampling method for the headspace volatile compound analysis of MAP packed beef steak (a-b).

Outcome 4: Development of an on-pack visual indicator of beef quality and freshness

On-pack sensors based on red cabbage extract (RC), black carrot extracts (BC) and chlorophenol red dye (CPR) have been developed and applied for monitoring beef quality and freshness. The sensors have an accurate response to the beef freshness at room temperature (**Figure 4a**) and under refrigerated conditions (4 °C) giving an intense, clearly visible colour change (**Figure 4b)** The colorimetric response of these sensors was correlated with the information of the surface microbial load to verify the sensor applicability as a real time indication of beef freshness at both refrigerated and ambient temperatures.

A manuscript of this chapter is under preparation for submission to *Elsevier Sensors and Actuators B (Chemical)*.

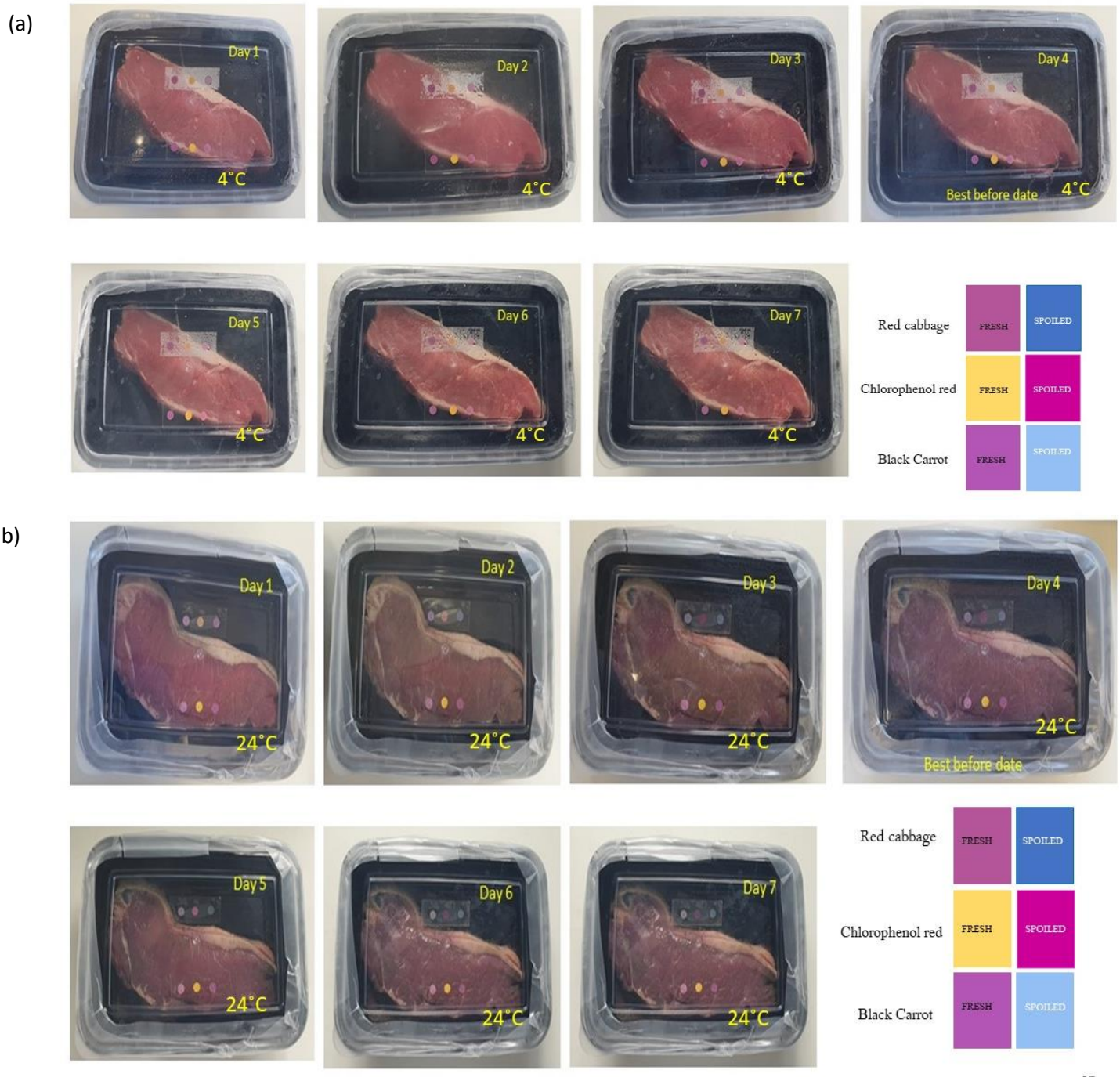

Figure 4: Sensor response to raw beef stored at (a) 4°C and (b) room temperature.

Benefits to industry

- A consumer survey was conducted and indicated that an on-pack visual sensor would be well received.
- Volatile compounds released from different commercial beef packaging systems were identified.
- A non-invasive sampling method that can be used to study the authentic headspace volatile profile of different foods and other products was developed.
- A prototype on-pack sensor based on volatiles detection was developed.
- The on-pack visual sensor requires less operator training to evaluate the meat quality and can be used for field applications, like home setting, supermarket, store etc.
- The sensor is user friendly, cheap, efficient, and a consumer could directly detect the meat freshness with an observable colour change.
- The developed sensor can not only be used in meat packaging, it can also be used for other food packaging (where pH change can be used as a parameter to detect spoilage) which expands the market and opens the scope of collaboration.

Future research and recommendations

- Integrate and test the developed sensor into existing MAP and other raw beef packaging systems.
- Cost analysis for large scale production, focussing on cost minimisation and logistics for supermarket role out.