Interim research report

Shelf life of frozen Australian red meat products

This paper summarises the interim findings of ongoing research commissioned by MLA to establish the practical shelf life (PSL) of frozen beef and lamb, such as would be exported from Australia.

1. Frozen meat trade

History

Freezing, as a method of preserving food, was known prior to modern technology enabled its widespread application.[1] Modern commercial mechanical refrigeration is suggested to have commenced in Sydney, Australia in 1861 and the first shipment of frozen meat from Sydney to London followed in 1868.[2] Over many years, frozen food and international trade in meat has flourished and enabled more countries to participate in global food chains.

Volume

In 2020, 6.4 million tonnes of frozen red meat[3] was exported around the world, the second highest volume on record and a trade worth US$28.2 billion. As highlighted in Figure 1, the global trade in frozen meat has more than doubled since 2000.

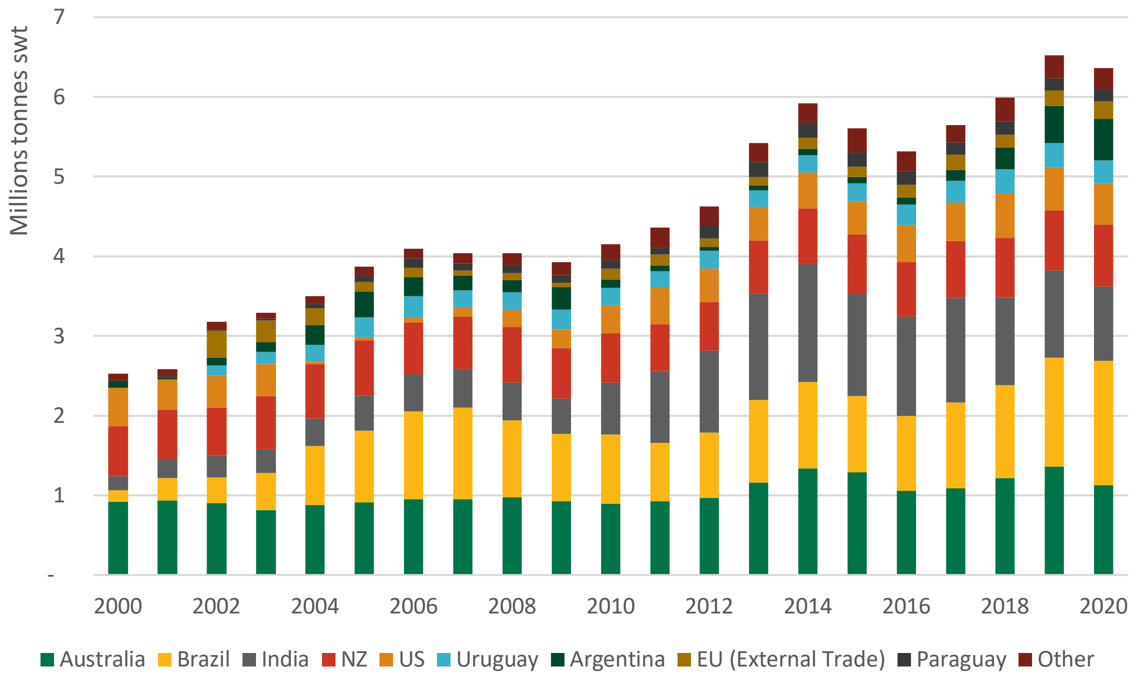

Figure 1. Frozen red meat exports by major exporting countries: includes frozen beef, buffalo meat and sheepmeat from major exporting countries (excludes intra-EU trade) in shipped weight (swt)

Australia is a major exporter of frozen meat and has a rich history of shipping product to over one hundred markets worldwide. Australia is consistently among the top-three exporters of frozen beef and sheepmeat over the last decade.

Australia exported more than 1.13 million tonnes of frozen beef and sheepmeat in 2020, with the bulk of shipments spread across North Asia, Southeast Asia, North America, the Middle East and Europe.

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[1] Lawrie, R.A. and D.A. Ledward (2006) Lawrie's meat science. 7th ed. Cambridge: Woodhead. p.213

[2] Frozen food - Wikipedia accessed 21.10.2021

[3] MLA calculations based on IHS Markit Global Trade Atlas data; includes frozen beef, buffalo meat and sheepmeat from major exporting countries

Table 1: Australian frozen meat and offal exports by country 2020 in Tonnes[4]

Export market	Beef	Pork	Sheepmeat	Offal	Total
China	186,676	0	145,819	11,549	344,044
US	144,488	0	38,104	5,712	188,304
Japan	152,046	630	7,377	14,486	174,539
Korea	134,103	1,303	10,058	22,944	168,407
Indonesia	57,568	25	1,202	42,900	101,696
Philippines	28,702	891	216	10,630	40,440
Malaysia	7,971	307	25,303	3,434	37,015
Vietnam	17,594	3,972	299	8,785	30,650
Taiwan	19,903	0	5,810	4,009	29,722
Hong Kong	3,379	886	4,141	20,096	28,502
PNG	3,302	4,031	12,564	5,302	25,198
Saudi Arabia	8,079	0	8,894	6,985	23,958
Singapore	6,276	1,106	11,043	3,156	21,582
Canada	11,077	0	5,363	1,447	17,888
UAE	3,981	11	7,238	3,972	15,201
Other	19,067	3,841	37,876	36,902	97,686
Total	**804,210**	**17,004**	**321,309**	**202,308**	**1,344,831**

2. Safety and quality of frozen meat

The International Institute of Refrigeration (IIR)[5] notes that 'the physical and biochemical reactions which take place in frozen food products lead to a gradual, cumulative and irreversible reduction in product quality such that after a period of time the product is no longer suitable for consumption (or the intended process)'.

During frozen storage microbiological growth is arrested, but meat will slowly deteriorate due to oxidative and other changes. Frozen storage life is normally limited by the development of adverse flavours caused by oxidative rancidity of fat. The temperature of storage, method of packaging and degree of saturation of the fat all affect the onset of these changes. The frozen storage life may also be reduced if the product is comminuted, because this process exposes more meat surfaces to oxygen.[6]

Microbiology

Many factors influence the growth and survival of microorganisms (bacteria, mould) in meat during freezing and frozen storage. However, the main factor affecting the growth of microorganisms during freezing is the availability of water (expressed as water activity). The transformation of water into ice significantly modifies the growth environment for microorganisms because water activity is progressively reduced preventing microbial growth.[7]

[4] MLA calculations based on IHS Markit Global Trade Atlas data

[5] Bøgh-Sørensen, L. (ed.) (2006) Recommendations for the Processing and Handling of Frozen Foods. Paris: International Institute of Refrigeration. p. 10

[6] Food Science Australia (2002) Shelf life of meat. https://meatupdate.csiro.au/Storage-Life-of-Meat.pdf

[7] James, SJ and C James (2002) Meat Refrigeration. Cambridge: Woodhead p.7

Microorganisms do not grow below about -10°C (mould growth being most noticeable on meat held at low temperatures), thus spoilage is only normally relevant to handling before freezing or during/after thawing.[8]

Chemistry

It is broadly accepted that fat oxidation remains the obstacle to very long-term storage of frozen meat.[9] The initial reaction is between a molecule of oxygen and a fatty acid to form a peroxide. The presence of peroxides in fat does not change the flavour; rather, it is the breakdown products of the peroxides which produce the unpleasant rancid odour and flavour and determines the acceptable shelf life of the meat.

Sensory

In cartons, 'freezer burn' is the main appearance problem that may frequently affect the appearance of meat. Freezer burn results from the desiccation of the surface tissues, which produces a dry, spongy layer that is unattractive and does not recover after thawing.[10]

While oxidation of oxymyoglobin can occur, affecting the colour of the meat,[11] it is expected that the unacceptable changes in flavour, stemming from oxidative rancidity of fat, is the most likely sensory change in product.[12]

3. Storage conditions

Temperature

Early last century, -10°C was regarded as a suitable temperature for storing frozen food. However, lower temperatures were recognised as being more suitable. In the late 1930s, the American Fruit and Vegetable Coalition advocated that a freezing temperature of 0°F (equivalent to -17.8°C) be maintained, largely on the basis that 0°F was a round number, rather than for scientific reasons[13]. The IIR note that -10°C is a satisfactory temperature for meat storage.[14] Lawrie[15] reported that it is customary in Britain to store frozen meat at -10°C and notes research reporting that fats of beef and lamb are relatively resistant to such oxidation and may still be good after 18 months storage at -10°C. Research conducted in New Zealand in the 1980s stored lamb at -10°C with satisfactory results for 14-18 months, depending upon processing conditions.[16] Storage at a higher temperature would require less energy, providing economic and environmental benefits.

In 1964, the International Institute of Refrigeration recommended a minimum temperature of -18°C for frozen food.[17] By 1966 the Codex Alimentarius Commission was considering standards on frozen foods and recommended that the temperature of product should be maintained at -18°C (0°F) and

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[8] James, SJ and C James (2002) Meat Refrigeration. Cambridge: Woodhead p.11
[9] James, SJ and C James (2002) Meat Refrigeration. Cambridge: Woodhead p.216
[10] James, SJ and C James (2002) Meat Refrigeration. Cambridge: Woodhead p.76-77
[11] James, SJ and C James (2002) Meat Refrigeration. Cambridge: Woodhead p.76-77
[12] Lawrie and Ledward. Lawrie's meat science. 7th ed. Cambridge: Woodhead. p. 226
[13] https://blog.liebherr.com/appliances/my/ideal-freezer-temperature/
[14] Bøgh-Sørensen, L. (ed.) (2006) Recommendations for the Processing and Handling of Frozen Foods. Paris: International Institute of Refrigeration. p. 117
[15] Lawrie and Ledward. Lawrie's meat science. 7th ed. Cambridge: Woodhead. p. 220, 226
[16] Winger, R. J. (1984). Storage life and eating-related quality of New-Zealand frozen lamb: A compendium of irrepressible longevity. In P. Zeuthen (Ed.), *Thermal processing and quality of foods* (pp. 541–543). London: Elsevier
[17] https://blog.liebherr.com/appliances/my/ideal-freezer-temperature

that any rise in the temperature of product during transportation and unloading should be limited to very brief periods and never be warmer than -15°C.[18]

The current Codex Alimentarius *Code of Practice* recommends distribution of quick-frozen foods should maintain a temperature of -18°C but permits competent authorities to allow -12°C during transport with the product temperature reduced to -18°C as soon as possible.[19]

Time of storage

The IIR notes that 'storage life of nearly all frozen foods is dependent on the temperature of storage' and makes recommendations on practical storage life (PSL). PSL is defined as 'the period of frozen storage at a given temperature during which the product retains its characteristic properties and remains suitable for consumption or the intended process'.[20] Few scientific publications present data on the PSL of meat at different storage temperatures.[21]

Regulation

Regulatory authorities in most countries do not mandate expiry dates, except where it can be scientifically shown that there is a food safety concern; rather, the convention in international trade is for the supplier to nominate a shelf life, which is usually applied to the product label (Table 2).

Table 2: Expiry date considerations for selected countries importing Australian frozen meats

Country	Requirements[22]
USA	Use-by dates may be printed on the label
EU	Labels on consumer-ready edible products must include the date of minimum durability, or, in the case of foodstuffs, which from a microbiological point of view are highly perishable, the 'use-by' date and any special storage conditions or conditions of use.
China	No requirements for frozen meat.
Japan	No known specific requirements for use-by dates and/or shelf life restrictions.
Korea	No known requirements for frozen meat. The shelf life for chilled beef must be determined by the manufacturer. [23]

4. Data on frozen storage of Australian Red Meat

Meat & Livestock Australia, the designated Australian Government research and development corporation for red meat production, conducted a study to establish the practical shelf life (PSL) of frozen beef and lamb, such as would be exported from Australia.

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[18] Joint FAO/WHO Program on Food Standards. Codex Alimentarius Commission. (1966) Report of the Second Session of the Joint ECE/Codex Alimentarius Group of Experts on Standardization of Quick (Deep) Frozen Foods. Annex I. Proposed Draft Provisional General Standard for Quick (deep) Frozen Foods at Step 3. ALINORM 66/25 October 1966.

[19] Codex Alimentarius Commission (2008). Code of Practice for the Processing and Handling of Quick Frozen Foods CAC/RCP8-1976. adopted 2008.

[20] Bøgh-Sørensen, L. (ed.) (2006) Recommendations for the Processing and Handling of Frozen Foods. Paris: International Institute of Refrigeration. p. 10

[21] James, SJ and C James (2002) Meat Refrigeration. Cambridge: Woodhead p.208,221

[22] Australian Government, Department of Agriculture, Water and the Environment. Manual of Importing Country Requirements.

[23] WTO case (DS-5,1995) United States v Korea. agreement to allow manufacturers of various products to determine their own shelf-life. https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds5_e.htm

Experiment design

Australian beef and lamb cuts (strip loin and eye of loin, respectively) and manufacturing meat of varying fat levels were frozen at -18°C prior to transport to the Food Refrigeration & Process Engineering Research Centre (FRPERC) at the Grimsby Institute (UK). The cartons were then stored at -12°C, -18 °C, and -24°C until sampling and testing.

The data for highest fat-containing manufacturing meat are presented below, with literature suggesting that these products will deteriorate the quickest. Sensory scores for fat flavour in minced, cooked patties and a measure of oxidative rancidity (TBARS) are presented here as sensitive indicators of shelf life (Figures 2 and 3). Campo et al.[24] investigated the flavour perceptions in beef and suggested that, as rancid flavours develop, there is a loss of desirable flavour notes. They reported that the higher the TBARS the less beef flavour could be perceived sensorially, with a strong relationship between TBARS level and perception of rancidity. They suggested that a TBARS value of around 2 could be considered the limiting threshold for the acceptability of oxidised beef.

A quantitative panel evaluation was carried out on the meat using approximately ten assessors. The panel evaluated the samples on a ten-point quality scale in which intensity (having a characteristic quality in a high degree) ranged from very low (1) to very high (10). Scores less than 4 represent samples approaching unacceptable flavour.

Results

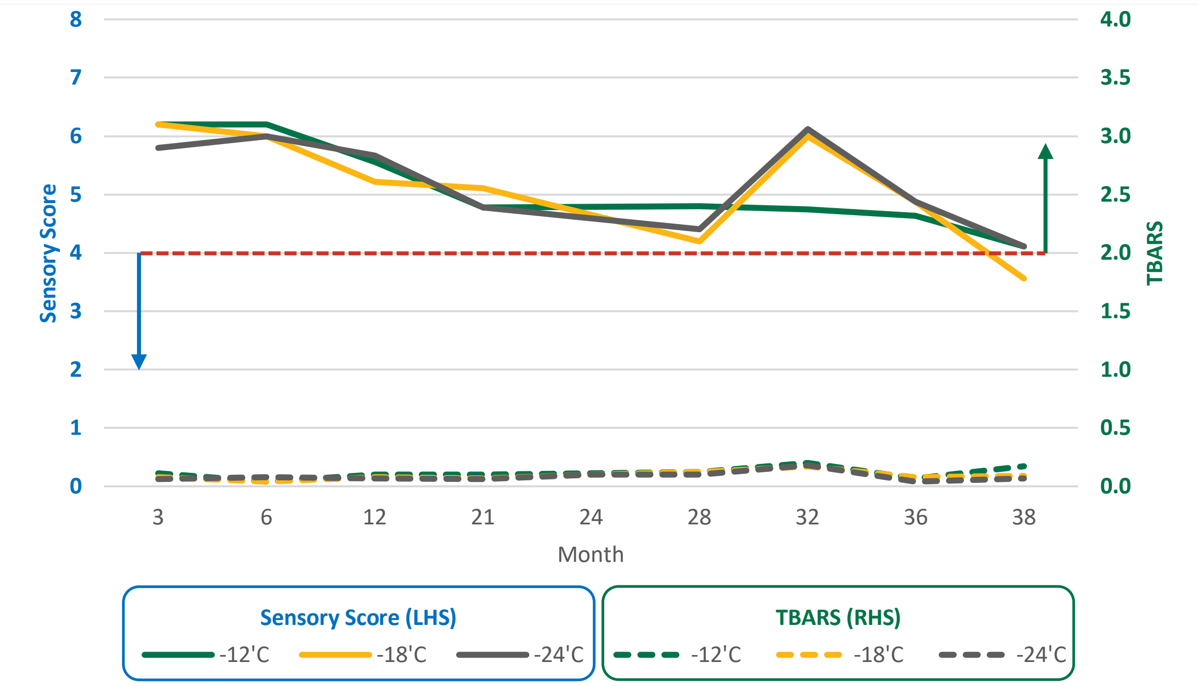

Figure 2. Frozen 65CL beef made into patties: mean sensory (solid line) and measure of oxidative rancidity [thiobarbituric acid reactive substances (TBARS) (mg malondialdehyde (MDA)/kg)] (Dashed lines) of samples measured at 3 (arrival), 6, 12, 21, 24, 28, 32, 36 and 38 months, stored at -12°C (green), -18°C (yellow) and -24°C (grey). The red dashed line represents a score approaching unfavourable sensory and oxidative rancidity (TBARS) results.

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[24] Campo MM, Nute GR, Hughes SI, Enser M, Wood JD, Richardson RI. Flavour perception of oxidation in beef. Meat Sci. 2006 Feb;72(2):303-11. doi: 10.1016/j.meatsci.2005.07.015

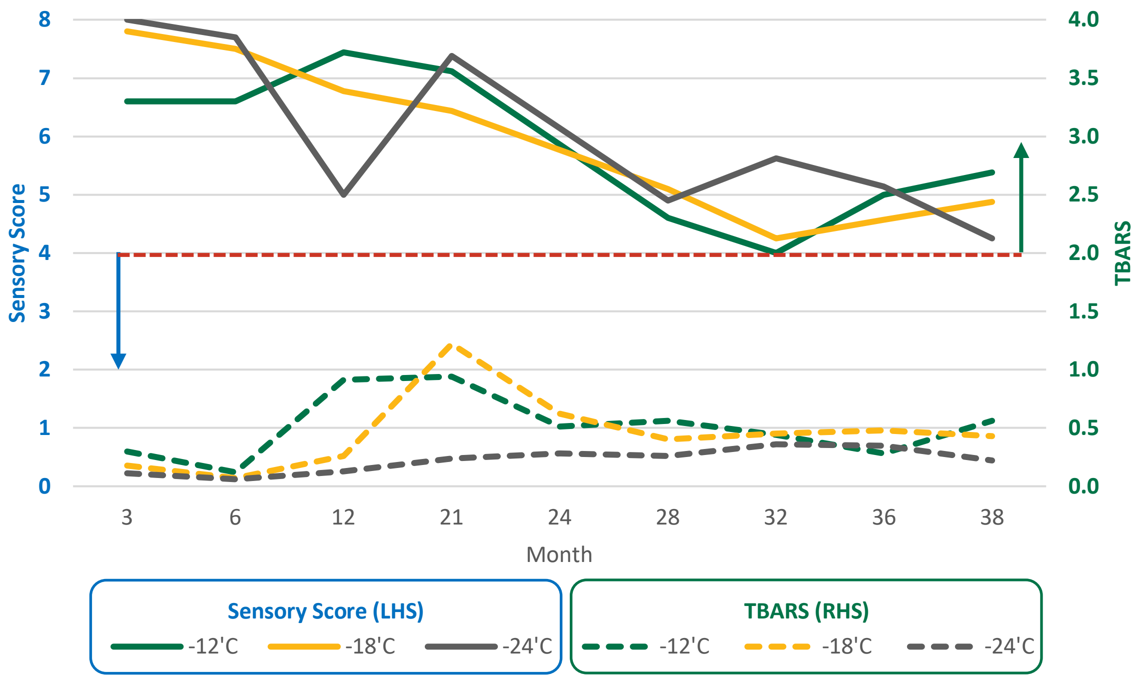

Figure 3. Frozen 65CL lamb made into patties: mean sensory (solid line) and measure of oxidative rancidity [thiobarbituric acid reactive substances (TBARS) (mg malondialdehyde (MDA)/kg)] (Dashed lines) of samples measured at 3 (arrival), 6, 12, 21, 24, 28, 32, 36 and 38 months, stored at -12°C (green), -18°C (yellow) and -24°C (grey). The red dashed line represents a score approaching unfavourable sensory and oxidative rancidity (TBARS) results.

In this work, no clear relationships/trends between sample type, storage temperature, and time of storage were apparent in the majority of the measured quality parameters, apart from those relating to lipid oxidation and sensory evaluation.

5. Recommendations

Storage temperature

While -18°C has become the standard temperature for the storage of frozen foods, red meat appears able to be stored successfully for many months or years at a temperature warmer than this threshold. No food safety hazards exist on frozen meat that has been held at, or reached, a temperature between -10°C and -18°C. Sensory degradation occurs only slowly at these temperatures and no food safety hazards arise.

Shelf life at -18°C

The world-leading Australian study demonstrated that if held at, or around, -18°C, frozen beef and lamb can be stored without significant sensory degradation for a period of over 36 months. No food safety hazards arise. Mandated shorter frozen shelf life requirements (such as 12 months) should be reviewed to reflect this evidence.