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Stability of Microbial and Chemical Indicators of the Minced Beef Meat under Freezing and Refrigerated Temperature

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Abstract. The microbial spoilage and chemical changes in minced beef meat were monitored during storage at freezing and refrigerating temperatures. Total viable count of *Pseudomonas*, *Streptococcus* faecal count, faecal coliform and *Staphylococcus aureus* in minced beef meat collected from supermarkets at day 0 were 4.3, 3.2, 2.5, 2.2 and 3.9 $\log_{10}$ CFU/g, respectively. These counts increased after 5 days of storage at 4±1 °C to 7.3, 7.1, 3.8, 5.0 and 3.3 $\log_{10}$ CFU/g, respectively. These counts decreased after 6 months at -10±1 °C to 3.2, 2.6, 2.0, 1.2 and 1.0 $\log_{10}$ CFU/g, respectively. The results also indicated that the total viable count of *Pseudomonas*, *Streptococcus* faecal count, faecal coliform and *Staphylococcus aureus* were higher in small butcher shop as compared to supermarket at day 0. On day 0 the thiobarbituric acid reactive in minced beef meat samples collected from supermarket and small butcher shop were 0.89 and 1.15 mg malonaldehyde/kg, respectively. After 5 days of storage at 4 °C, the thiobarbituric acid reactive in minced meat beef collected from supermarket and small shop increased and reached upto 2.95 and 3.74 mg malonaldehyde/kg, respectively. It increased to 3.02 in minced beef from supermarket, and 3.85 mg from small shop after 6 months at -10±1 °C. Lightness, redness and yellowness of minced beef meat decreased, when meat was kept under cooling and freezing temperature, however, lightness, redness and yellowness of minced beef meat were higher in density in supermarket samples than those of meat obtained from small butcher shops.

Keywords: cooling, freezing temperature, minced beef meat, TBARS, colour

Introduction

The minced beef meat is of high value in terms of nutrition and economy. It contains most of the nutrients specially essential amino acids. The minced beef meat is used in many types of meals. This type of meat is highly perishable due to its suitablity for the growth of microorganisms as the large exposed surface area facilitates spoilage. Fresh minced beef meats are commonly marketed at refrigerated temperature (4±1 °C). Total count and coliform bacteria are good indicators of the hygienic quality of minced meat (Skrökki, 1997). *Enterobacter*, Lactobacilli, Pseudomonads, *Brochothrix thermosphacta* and *Shewanella putrefaciens* are responsible for spoilage of fresh meat and meat products (Huffman, 2002; Garbutt, 1997). The chilled temperatures with high moisture will favour the *Pseudomonas alcaligenes*. Extended refrigeration may have the growth of *Pseudomonas*, *Acinetobacter* and *Moraxella* and causes spoilage of fresh meat. Yeasts may grow under aerobic conditions on meat and causes sliminess, lipolysis, discolourations, off odours and taste. Coliform is often used as hygiene indicator of foods of animal origin. The presence of coliforms in meat indicates that inadequate treatment or post-process contamination occur during handling or manufacturing stages (Crowley *et al*., 2005). Meat is contaminated with many types of microorganisms during slaughtering, evisceration, chilling, handling, and grinding (Jay, 2002). *Pseudomonas* spp. are ubiquitous and able to grow aerobically at low temperatures and are generally recognized to dominate in meat during storage at refrigeration temperature. Many *Pseudomonas* are responsible for spoilage of meat and meat products by degradation of glucose and amino acid, even at refrigeration temperatures (Koutsoumanis *et al*., 2006; Skandamis and Nychas, 2005; Ellis and Goodacre, 2001; Labadie, 1999). Also *Serratia*, *Enterobacter*, *Pantoea*, *Proteus*, and *Hafnia*, often contribute to meat spoilage (Jay *et al*., 2003; Gram *et al*., 2002; Labadie, 1999; Nychas and Drosinos, 1999; Borch *et al*., 1996). Podpeèan *et al*. (2007), isolated *S. aureus* in 62.5% (10/16) of specimens from ground meat. *S. aureus* grows, when meat is stored in an inadequate environment for longer period of time. During refrigeration, the hygienic quality of meat declines

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rapidly due to microbial growth through contamination from different sources and lipid oxidation, which eventually leads to meat spoilage. Reduction of contamination, cross contamination, delaying or inhibiting spoilage and growth of pathogenic bacteria improves meat quality, enhance safety and increase its shelf life. There are some factors, which can be effective for keeping meat quality that includes temperature, time of ageing and packaging (Beriain and Lizaso, 1997). Minced beef meat is susceptible to microbial contamination during processing and handling stages (Nam and Ahn, 2003). According to Irkin *et al*. (2011), minced beef meat is acceptable, when the total count is in the range from 5×10^6 to 1×10^7 CFU/g.

Oxidation and rancid off-flavour can occur during refrigerated and frozen storage (Pearson and Young, 1989). Meat colour is the main factor and discolouration and oxidative rancidity and off-flavour in red meat are related to the oxidation of myoglobin and the autoxidation of fat, which affects the consumer buying decisions (Brewer *et al*., 2002; Faustman and Cassens, 1990). Aerobic bacterial growth during logarithmic phase increases the rate of beef oxidation due to its high oxygen demand for the oxidation of myoglobin to metmyoglobin (Seideman *et al*., 1984). The sensory deterioration of minced beef meat is due to the growth of microorganisms and consumption of meats nutrients such as sugars and free amino acids that liberate undesirable volatile metabolites. Off-odours such as "cheesy" or "buttery" odours usually happens when the microbial load in minced beef meat over 10^7 CFU cm^2. Off-odours "fruit" evolves, when microbial loads increase and become moldy due to free amino acids consumed by microorganisms and numbering over 10^9 CFU cm^2 (Ercolini *et al*., 2006; Jay, 2000; Dainty *et al*., 1985).

Meat processors usually need meat of high quality with low microbial load. Therefore, it is very important for meat manufacturers to collect data that can be used by meat industry to validate or change their current practices of processing in order to increase the ground beef quality, safety and shelf life.

The main objective of this study was to evaluate the effects of cooling and freezing temperature (4±1 °C and -10±1 °C) on the microbial and chemical quality of minced beef meat.

Materials and Methods

Sample preparation. Minced beef meat samples were collected from four supermarkets butcheries and four butcher shops in Riyadh city area (capital of Saudi Arabia). About 250±10 g of each of the ground meat samples were collected, packed in sterile polyethylene bags. The samples were kept at low temperature (0/ -1 °C) and transported to the lab within 1 h, each replica consisted of 32 samples under aseptic conditions. On arrival at the laboratory, the samples were analysed for microbial count, colour and lipid oxidation. The rest of the samples were stored at temperatures appropriate to the study. Each batch consisted of 16 samples of minced beef collected from supermarkets butcheries and 16 samples collected from small shops. Eight samples from supermarkets and 8 samples from the small shops were stored at 4±1 °C, while, 8 samples each from supermarkets and small shops were stored at -10±1 °C.

Storage. Lipid oxidation, colour and microbial analysis were carried out at 0, 1, 3 and 6 months of frozen storage (-10±1 °C) and at 0, 2, 4 and 5 days of refrigerated storage (4±1 °C). Samples for lipid oxidation, colour and microbial analysis were stored without vacuuming in sterile bags.

Microbiological analyses. The microbial load in minced beef was determined at the beginning (before storage) using FDA procedures (Koch *et al*., 2001). Five methods were used for identification and enumeration of microorganisms in ground beef samples: total viable cell count of *Pseudomonas*, *Streptococcus*, faecal coliform and *S. aureus.* Aseptically, approximately 25 g of minced beef meat were 10-fold diluted in 225 mL buffered peptone water and homogenised in a stomacher bag for 1 min. Serial decimal dilutions were made and the following analyses were carried out on agar plates in duplicate: (1) total viable count on aerobic plate count incubated at 30 °C for 48 h (2) *Pseudomonas* count on aerobic *Pseudomonas* media incubated at 30 °C for 24 h (3) *Streptococcus* count on tryptic soy agar incubated at 35 °C for 24 h (4) faecal coliform at aerobic Violet Red Bile Agar incubated at 30 °C for 24 h (5) *S. aureus* using aerobic *Staphylococcus* medium 110 incubated at 35 °C for 48 h.

Lipid oxidation measurement. Lipid oxidation was evaluated by the determination of 2-thiobarbituric acid

reactive substances (TBARS), which is a good indicator for measuring the lipid peroxidation in minced meat, due to its speed and simplicity (Raharjo and Sofos, 1993; Shahidi and Hong, 1991). TBARS is formed in meat as a byproduct of lipid peroxidation that are generated under conditions of oxidative stress. It is component, which results from the decomposition of polyunsaturated fatty acid lipid peroxides. TBARS determination were performed since this parameter is one of the most widely used tests for evaluating the extent of secondary oxidation, owing to its sensitivity and relatively simple procedure (Fernindez *et al*., 1997). TBARS values were calculated from a standard curve of malonaldehyde (MA) and expressed as mg MA/kg minced beef meat sample.

Meat colour measurement. A Hunter-Lab Digital Colour Difference Meter was used to measure *L* (luminosity), *a* (redness), and *b* (yellowness) values. Three measurements were taken uniformly spaced over the surface and the colourimetric values were averaged.

Statistical analysis. The factorial experiment in the completely randomised design was done with three replicates. Three replica was done for each independent. ANOVA for the factorial experiment in the completely randomised design was carried out according to Gomez and Gomez (1984). The means were compared using the least significant difference (LSD) at the 5% level according to Waller and Duncan (1969). SAS software package was used (SAS, 2001).

Results and Discussion

Microbial load, lipid oxidation and colour changes are the most important quality criteria for storage of minced meat (Anthoula *et al*., 2012; Ozlem *et al*., 2011; Brooks *et al*., 2008). The microbiological quality of frozen and cooling packed minced meat are shown in Table 1. The initial total viable count on minced meat samples collected from supermarkets and small shops were 4.3 and 4.8 $\log_{10}$ CFU/g, respectively. A similar level of initial contamination was reported by Anthoula *et al*. (2012); Coleen *et al*. (2012); Ozlem *et al*. (2011) and Brooks *et al*. (2008). On day 0, 2, 4 and 5 there was a significant decrease ($P<0.05$), in the number of total viable bacteria between cooled minced meat samples collected from supermarkets and samples collected from small butcher shops, respectively. The total viable count increased rapidly on samples packed in air and stored in refrigerator, which could be due to the grounding process, initial contamination and cold storage (Papadopoulou *et al*., 2012; Ozlem *et al*., 2011). A similar trend was observed for *Pseudomonas*. In all minced meat samples packed in air and stored chilled, *Pseudomonas* were found to be the dominatinant flora. Similar results were also reported by Abderrahmane *et al*. (2011) and Brooks *et al*. (2008). Meat is a highly perishable food product which, unless correctly stored, processed, packaged and distributed, spoils quickly and becomes hazardous due to the microbial growth (Odekerken *et al*., 2012; Papadopoulou *et al*., 2012; Zhou *et al*., 2010; Nychas *et al*., 2008). High counts in meat indicates contaminated raw materials or unsatisfactory processing or cross contamination after processing from a sanitary point of view (ICMSF, 1988).

Staphylococcus aureus is a major human pathogen associated with a wide spectrum of diseases from relatively benign skin infections to life-threatening endocarditis, toxic shock syndrome and necrotising pneumonia (Luning *et al*., 2011; Diane *et al*., 2010). This bacterium can contaminate several foods, including processed meat products and minimally processed ready-to-eat vegetables (El-Hadedy and Abu El-Nour, 2012; Diane *et al*., 2010). The initial contamination levels of *S. aureus* on minced meat samples collected from supermarkets and small shops were 2.6 and 3.3 $\log_{10}$ CFU/g, respectively. The presence of pathogens in the food supply in low numbers is considered a major cause of world-wide gastrointestinal disease (Luning *et al*., 2011). The number of *S. aureus* on minced meat stored at 4 °C increased, significantly ($P<0.05$), during 5 days of storage. In contrast the number of *S. aureus* on minced meat stored frozen (at -10 °C), significantly decreased ($P<0.05$), on all samples during 180 days of storage. It could be concluded that frozen storage reduces the risk of *S. aureus* pathogen on minced meat.

High counts of coliforms indicated poor hygiene in the food supply chain (George *et al*., 2011; Luning *et al*., 2011; Norrung and Buncic, 2008). The initial contamination level of fecal coliform on minced meat samples collected from supermarkets and small butcher shops were 2.2 and 4 $\log_{10}$ CFU/g, respectively. The $\log_{10}$ CFU/g of faecal coliform on minced meat stored in refrigerator at 4 °C, significantly increased ($P<0.05$), during 5 days of storage. In contrast all samples stored frozen at -10 °C, the $\log_{10}$ CFU/g of faecal coliform, significantly decreased ($P<0.05$), during 180 days of storage. Similar trend was observed for *Streptococcus.*

Table 1. The growth of microbial indicators in minced meat stored at 4 °C and -10 °C collected from supermarkets and small shops at Riyadh

Location	Chilled minced beef (4 °C)				Frozen minced beef (-10 °C)			
	Day 0	Day 2	Day 4	Day 5	Day 0	Day 30	Day 90	Day 180
	Total viable count (log_{10} CFU/g)				Total viable count (log_{10} CFU/g)			
Supermarkets	4.3^{Aa}	5.2^{Ba}	6.1^{Ca}	7.3^{Da}	4.3^{Aa}	4.8^{Ba}	3.7^{Ca}	3.2^{Da}
SD	0.3	0.4	0.2	0.5	0.25	0.6	0.4	0.4
Small butcher shops	4.8^{Ab}	5.7^{Bb}	6.6^{Cb}	7.8^{Db}	4.8^{Ab}	5.3^{Bb}	4.1^{Cb}	3.5^{Da}
SD	0.6	0.15	0.7	0.8	0.5	0.3	0.3	0.2
	Pseudomonas (log_{10} CFU/g)				*Pseudomonas* (log_{10} CFU/g)			
Supermarkets	3.2^{Aa}	4.2^{Ba}	4.9^{Ca}	7.1^{Da}	3.2^{Aa}	4.1^{Ba}	3.1^{Ca}	2.6^{Da}
SD	0.4	0.2	0.5	0.4	0.2	0.4	0.1	0.3
Small butcher shops	3.8^{Ab}	4.9^{Bb}	5.5^{Cb}	7.4^{Db}	3.8^{Ab}	4.4^{Bb}	3.6^{Cb}	3.0^{Da}
SD	0.5	0.2	0.7	0.7	0.25	0.3	0.2	0.4
	Streptococcus faecal (log_{10} CFU/g)				*Streptococcus* faecal (log_{10} CFU/g)			
Supermarkets	2.5^{Aa}	3.0^{Ba}	3.3^{Ba}	3.8^{Ca}	2.5^{Aa}	2.0^{Ba}	2.5^{ACa}	2.0^{BDa}
SD	0.2	0.2	0.15	0.4	0.2	0.2	0.1	0.2
Small butcher shops	3.9^{Ab}	4.6^{Bb}	4.8^{Bb}	5.3^{Cb}	3.9^{Ab}	3.0^{Bb}	3.1^{Ab}	2.6^{Da}
SD	0.3	0.3	0.4	0.5	0.35	0.4	0.2	0.25
	Faecal coliform (log_{10} CFU/g)				Faecal coliform l (log_{10} CFU/g)			
Supermarkets	2.2^{Aa}	3.7^{Ba}	4.5^{Ca}	5.0^{Da}	2.2^{Aa}	2.1^{Aa}	1.6^{Ba}	1.2^{Ca}
SD	0.3	0.3	0.5	0.4	0.1	0.15	0.3	0.4
Small butcher shops	4.0^{Ab}	4.3^{Ab}	4.9^{Bb}	5.6^{Cb}	4.0^{Ab}	3.5^{Bb}	2.3^{Cb}	1.5^{Da}
SD	0.1	0.2	0.4	0.6	0.3	0.4	0.2	0.2
	Staphylococcus aureus (log_{10} CFU/g)				*Staphylococcus aureus* (log_{10} CFU/g)			
Supermarkets	2.6^{Ab}	4.0^{Bb}	3.8^{Ba}	3.3^{Ca}	2.6^{Ab}	2.4^{Ab}	1.4^{Bb}	1.0^{Da}
SD	0.3	0.3	0.2	0.2	0.1	0.3	0.2	0.1
Small butcher shops	3.3^{Aa}	4.5^{Ba}	3.9^{Ca}	3.4^{Da}	3.3^{Aa}	2.3^{Ba}	1.5^{Ca}	1.2^{Da}
SD	0.2	0.4	0.3	0.2	0.4	0.2	0.1	0.1

Log_{10} CFU/g values stated refer to three samples; values with the same superscripts in the same horizontal row (A-D) or vertical column (a-b) are not significantly different at (P=0.05); SD: standard deviation.

Generally, all microbial groups showed viable counts higher for samples stored chilled than those frozen. Meanwhile, samples collected from small butcher shops showed higher viable counts as compared to samples collected from supermarkets. The low number of viable counts minced beef meat in supermarkets may be due to practicing good sanitation and food handling techniques. After 180 days of storage at -10 °C, there were significant decreases ($P<0.05$), in the number of total viable bacteria, *Pseudomonas*, faecal coliform, *Streptococcus* and *S. aureus*, on minced meat samples, collected from supermarkets and small shops as compared to the initial number (day zero). The frozen storage for minced beef meat enhanced the microbiological quality and reduced the risk of pathogens. Although the hygienic quality of minced meat was still low, due to the high initial contamination level of pathogenic bacteria.

Lipid oxidation is one of the most important causes of minced meat deterioration during refrigerated or frozen storage, which affects fatty acids, particularly polyunsaturated fatty acids. This lipid auto oxidative degradation gives products that changes the meat quality, e.g., the

colour, aroma, flavour, texture and even the nutritive value (Descalzo and Sancho, 2008; Duong *et al*., 2008; Balentine *et al*., 2006; Montgomery *et al*., 2003). The method of measuring oxidative stress by TBARS method is the best way for screening and monitoring the lipid peroxidation, a major indicator of oxidative stress (Armstrong,1998). TBARS content of minced beef collected from supermarkets and small butcher shops stored in the refrigerator at 4 °C and frozen at -10 °C is shown in Table 2. The initial TBARS number was 0.89 and 1.15 mg MA/kg of minced beef collected from supermarkets and small shops, respectively. Values detected in fresh minced meat were in agreement with the published data (Ozlem *et al*., 2011; Brooks *et al*., 2008). After 4 days of storage at 4 °C the number of TBARS increased rapidly and reached to 1.88 and 2.37 mg MA/kg in samples collected from supermarkets and small butcher shops, respectively. Lipid oxidation was particularly pronounced in ground meats, where, the disruption of muscle cell structure exposed lipid components to oxygen (Ozlem *et al*., 2011; Duong *et al*., 2008; Balentine *et al*., 2006). Meanwhile, the number of TBARS, of samples stored frozen increased at a slower rate as compared with samples stored chilled. Vieira *et al*. (2009), stated that TBARS of fresh meat was, significantly, lower than meat stored for 90 days at -20 °C. Such observations indicate that frozen storage is not necessarily sufficient to prevent oxidation from occurring. A similar trend was obtained in this study. According to Coleen *et al*. (2012) and Estévez (2011) the optimum temperature for the frozen storage of meat has been reported to be -40 °C. This fraction of water is believed to be bound to other food constituents and thus is chemically inactive (Coleen *et al*., 2012; Singh and Heldman, 2001; Nesvadba, 2008). The chemical reactions can occur during stored ground beef at 4 °C that initiate primary lipid oxidation (peroxidation) in the meat (Lynch *et al*., 2001).

Meat purchasing decisions are influenced more by colour consideration than any other quality factor because consumers use discolouration as an indicator of freshness and wholesomeness (Mancini and Hunt, 2005). The colour of muscle depends on the amount and oxidation/ reduction state of myoglobin (Ozlem *et al*., 2011; Mohamed *et al*., 2008; Mancini and Hunt, 2005). The effect of cold and frozen storage on colour properties (*L**, *a** and *b** values) of minced beef meat collected from supermarkets and small shops is shown in Table 3.

The data indicate that lightness, redness and yellowness in minced beef meat collected from supermarkets were higher in density than those of collected from small butcher shops. Lightness, redness and yellowness in minced beef meat decreased during storage in cooling and freezing temperatures. The results of colour confirmed those obtained for microbiological quality (Table 1) and lipids oxidation, TBARS (Table 2).

The shelf life of minced meat is limited because the large exposed surface area facilitates spoilage. The rate of deteriorative changes depends on meat composition, hygienic practices during cutting, grinding and preparation and, finally, storage conditions (Anthoula *et al*., 2012; Limbo *et al*., 2010). The results of microbiology, lipid oxidation and colour indicate that the shelf life of samples, stored chilled at 4 °C and frozen at -10 °C were 4 and >90 days, respectively. Microbial quality, lipid oxidation and discolouration are the causative spoilage of minced meat stored chilled. Meanwhile, lipid oxidation and discolouration are mainly the causative spoilage of samples stored frozen.

Table 2. Malonaldehyde value of minced meat collected from supermarkets and small butcher shops at Riyadh

Location	Refrigerated minced beef (4 °C) Malonaldehyde mg/kg				Frozen minced beef (-10 °C) Malonaldehyde mg/kg			
	Day 0	Day 2	Day 4	Day 5	Day 0	Day 30	Day 90	Day 180
Supermarkets	0.89^{Aa}	1.48^{Ba}	1.88^{Ca}	2.95^{Da}	0.89^{Aa}	1.65^{Ba}	1.69^{Ca}	3.02^{Da}
SD	0.10	0.15	0.20	0.40	0.20	0.20	0.10	0.20
Small butcher shops	1.15^{Ab}	1.74^{Bb}	2.37^{Cb}	3.74^{Db}	1.15^{Ab}	1.87^{Bb}	2.10^{Cb}	3.85^{Db}
SD	0.30	0.20	0.10	0.50	0.20	0.15	0.30	0.40

Each number is mean of three replicates; values with the same superscripts in the same horizontal row (A-D) or vertical column (a-b) are not significantly different at (P=0.05); SD = standard deviation.

Table 3. Colour of minced meat collected from supermarkets and small butcher shops at Riyadh

Location	Chilled minced beef (4 °C)				Frozen minced beef (-10 °C)			
	*L**				*L**			
	Day 0	Day 2	Day 4	Day 5	Day 0	Day 30	Day 90	Day 180
Supermarkets	41.4^{Aa}	40.9^{Ba}	39.6^{Ca}	37.9^{Da}	41.4^{Aa}	39.1^{Ba}	38.7^{Ca}	37.63^{Da}
SD	5.0	3.0	6.0	4.0	5.0	4.0	5.0	4.0
Small butcher shops	40.3^{Ab}	40.4^{Aa}	39.1^{Ca}	38.0^{Ca}	40.3^{Ab}	38.8^{Bb}	38.1^{Cb}	37.42^{Db}
SD	3.0	5.0	4.5	3.0	6.0	3.0	5.0	4.3
	*a**				*a**			
Supermarkets	16.4^{Aa}	15.34^{Ba}	12.2^{Ca}	9.13^{Da}	16.4^{Aa}	15.1^{Ba}	12.7^{Ca}	$8.85.6^{Da}$
SD	2.0	1.7	2.1	0.95	1.20	1.7	1.3	1.1
Small butcher shops	15.1^{Ab}	13.4^{Bb}	10.8^{Cb}	8.42^{Db}	15.1^{Ab}	13.2^{Bb}	11.4^{Cb}	7.92^{Db}
SD	1.3	1.6	1.2	0.65	1.30	1.5	1.3	0.95
	*b**				*b**			
Supermarkets	16.2^{Aa}	$15..1^{Ba}$	13.9^{Ca}	12.2^{Da}	16.2^{Aa}	15.5^{Aa}	14.1^{Ba}	$11..7^{Ca}$
SD	2.0	1.7	1.4	1.2	2.1	1.8	1.1	1.3
Small butcher shops	15.7^{Ab}	14.8^{Bb}	13.3^{Cb}	11.7^{Db}	15.7^{Ab}	13.7^{Bb}	13.5^{Cb}	10.4^{Db}
SD	1.5	1.5	1.	1.2	1.6	1.4	1.9	1.1

Each number is mean of three replicates; values with the same superscripts in the same horizontal row (A-D) or vertical column (a-b) are not significantly different at (P =0.05); SD = standard deviation; *L** = lightness; *a** = redness; *b** = yellowness.

Conclusion

From the results, it is clear that the refrigerator temperature was not sufficient to inhibit the growth of microorganisms and enzymes work and freezer temperature was sufficient to inhibit the growth of microorganisms, but did not stop the enzymes activity. It was also noted that the minced beef meat from supermarkets were lower in the microbial load and the percentage of rancidity. The spoilage of minced meat stored at 4 °C is mainly due to microbial growth, lipids oxidation and discolouration. Meanwhile, the deterioration of minced meat stored at -10 °C is mainly due to lipids oxidation and discolouration. Although freezing storage improved the microbial quality of minced meat, the hygienic quality of frozen meat was still low due to the high initial contamination level from pathogen and spoilage bacteria. Further studies are needed to evaluate the roots of contamination in minced meat industry to reduce the contamination level, improve safety, quality and increase its shelf life.

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