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Review Article

Microbiological Quality of Rabbit Meat in Egypt and Worldwide: A Review

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Abstract

Rabbit meat and offal are considered as valuable sources of high biological value animal protein. Rabbit meat is rich in essential amino acids, low in cholesterol and contains considerable amounts of trace elements such as calcium, magnesium, and zinc. However, rabbit meat is also implicated in the transmission of foodborne pathogens such as *Staphylococcus aureus*, *Salmonella* spp., *E. coli*, and *Pseudomonas* spp. Few reports had reviewed the microbiological quality of rabbit meat either worldwide or in Egypt. In this review, we will summarize the available literature about the microbiological status of rabbit meat and offal. Moreover, the potential human health risks associated with the occurrence of such foodborne pathogens in rabbit meat, and their effect on the shelf life of meat will be discussed. In addition, suggestions on how to improve the microbiological quality of rabbit meat and to extend its shelf life will also be introduced.

KEYWORDS
Rabbit meat, Offal, Microbiological quality, Egypt

INTRODUCTION

Rabbit meat production is a major livestock activity in most Mediterranean countries, and the rabbit meat industry is well-developed in many others. Rabbits have a high fertility rate, rapid growth rates, a high feed efficiency and early marketing age, high muscle-bone ratios, and a small land area requirement (Cambero *et al*., 1991). This implies that the rabbit has a practical future as a livestock species in large-scale production. According to studies, rabbit meat has a high protein content and low levels of sodium, fat, and cholesterol, making it an excellent food for human consumption (Fernandez-Esp and O'Neill, 1993).

In Egypt, rabbits have traditionally been raised in small colonies in Egyptian backyards to supplement family income, but in recent decades, rabbit breeding has become a unique source of meat production. Rabbits are regarded as ideal meat-producing animals due to their short gestation periods, short life cycles, and high feed conversion rate. It is distinguished by low production costs and limited breeding space. Similarly, the economic benefits of rabbit skin fur production and the ideal experimental laboratory animals. The incorporation of rabbit meat into the human diet would benefit human health because it contains lean meat with high biological value, as well as high levels of unsaturated fat and low cholesterol content (Abd-Allah and Abd-Elaziz, 2018).

Rabbit meat is rich in essential and non-essential amino acids as the essential amino acids were found in the following order in the meat samples from the New Zealand White breed: lysine > isoleucine > valine > methionine > threonine > histidine > phenylalanine > leucine. The main difference between meat samples from the Egyptian Balady breed and the New Zealand White breed was that the levels of phenylalanine were higher than those of leucine, which may be related to their genetic build-up. Although slightly different, the amino acid composition of meat samples from the California breed was as follows: lysine > leucine > valine > threonine > isoleucine > phenylalanine > histidine > methionine (Morshdy *et al*., 2022).

Despite these facts about the nutritive value of rabbit meat, it is also implicated in the transmission of several foodborne pathogens leading to severe adverse health implications (Rodríguez-Calleja *et al*., 2004; Nakyinsige *et al*., 2015). In this mini review, we will summarize the available literature about the microbial quality of rabbit meat worldwide, and in Egypt.

Microbial quality of rabbit meat in Egypt

There is no doubt that foodborne pathogenic bacteria cause illness and death for many people each year, at a high economic and human cost. In Egypt, several studies on the microbiological quality of red meat, poultry, and their products have been conducted (El-Ghareeb *et al*., 2009; Darwish *et al*., 2018; Morshdy *et al*., 2018; Saleh *et al*., 2020). However, there is some uncertainty about the microbiological quality of rabbit meat, which, like many raw foods of animal origin, may be contaminated with organisms of various types, including potentially pathogenic bac-

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teria. There are two major sources of microbial contamination of rabbit meat that cause foodborne diseases. Pathogenic bacteria are carried by the living animal or found in the processing environment. Bacteria from the animal may contaminate the carcass during slaughter and then be distributed via the slaughter cut or via raw meat intended for further processing (Borch and Arinder, 2002).

In this regard, bacteriological testing was performed on 40 New Zealand white rabbits, 20 freshly slaughtered rabbits from an experimental farm, and 20 processed rabbit carcasses from grocery stores in Beni-Suef city. The mean values of aerobic plate counts at 37 °C and 1°C, Enterobacteriaceae counts, *Pseudomonas* counts, and *Staphylococcus* counts of freshly slaughtered rabbits were 10^4±2x10^3, 8x10^2±10^2, 6x10^2±10^2, 3x10^2±10^2, and 10^2±60 cfu/g, respectively, while the equivalent values were 8x10^5±3x10^4, 2x10^5±10^4, 4x10^4± 8x10^3, 2x10^4±6x10^3, and 4x10^3±4x10^2 cfu/g of processed rabbit carcasses from grocery stores, respectively. When compared to processed rabbit carcasses from grocery stores, freshly slaughtered rabbits had a lower bacterial load. *Salmonella Typhimurium*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* were isolated from processed rabbit carcasses, as well as *Escherichia coli* and *Listeria monocytogenes*. *Yersinia enterocolitica* was not isolated from any of the samples tested (Khalafalla, 1993).

The initial counts of aerobic mesophilic bacteria, psychrophilic bacteria, enterobacteriaceae, moulds and yeasts in rabbit meat samples were found to be relatively high, with mean log10 counts of 6.021, 5.888, 4.785, and 4.886 cfu/g, respectively. This reflects the possibility of cross contamination during slaughter, which has a significant impact on carcass bacterial status (Badr 2004). Furthermore, the aerobic plate count (7.82±0.34 $\log_{10}$ CFU/g), *Staphylococcus* (5.32±0.24 $\log_{10}$ CFU/g), and Enterobacteriaceae (5.72±0.26 log10 CFU/g) in the chilled muscles of the rabbit. Such counts were reduced to 5.92±0.21, 4.46±0.19, and 4.11±0.19 $\log_{10}$ CFU/g when treated with 1% of lemon grass oil and to 6.04±0.22, 4.55±0.18, and 4.18±0.27 $\log_{10}$ CFU/g when treated with 0.5% of 0black seed oil (Morshdy *et al*., 2021).

In a recent study by Mahmoud *et al*. (2022), they investigated the microbiological status of rabbit carcasses retailed in Zagazig City, Sharkia Governorate, Egypt. During 2022, authors collected eighty random samples of fresh rabbit meat cuts (shoulder, loin, ribs, and thigh regions). The investigated parameters were Aerobic plate count (APC), Enterobacteriaceae, total mould and yeast counts, as well as the isolation and identification of *E. coli* and *Salmonella* spp. The mean APC and Enterobacteriaceae values for shoulders were 1.1x10^6 and 4.7x10^4 CFU/g, 9.6x10^5 and 5.7x10^4 CFU/g for ribs, 1.0x10^6 and 5.1x10^4 CFU/g for loins, and 1.2x10^6 and 6.0x10^4 CFU/g for thigh samples, respectively. Furthermore, the total mould and yeast count ranged from 2.6x10^4 to 1.9x10^5. *Salmonella*e was found in 6 (30%), 7 (35%), 6 (30%), and 4 (20%) of shoulder, ribs, loin, and thigh regions, respectively. *E. coli*, on the other hand, was found in 18 (90%), 16 (80%), 15 (75%), and 19 (95%) of the rabbit meat samples tested. The findings suggested that fresh rabbit meat cuts might contain a variety of microorganisms from various sources, emphasizing the importance of strict sanitary precautions during slaughtering.

Microbial quality of rabbit meat worldwide

The total rabbit meat production is reaching over one million tons. Despite being sold and eaten all over the world, very little is known about the microbiological quality of rabbit meat. In Spain which is the third most producer of rabbit meat in the world, the indicator organisms, spoilage flora, sensory quality, and some physicochemical characteristics of chilled rabbit corpses that had been stored refrigerated in air for 24 hours postmortem and prepackaged meat that had been chilled in air for 0 to 3 days at the retail level were examined by Rodríguez-Calleja *et al*. (2004). Their obtained results indicated that the mean total bacterial count for rabbits dressed manually at a small abattoir was substantially lower than it was for carcasses dressed in automated slaughter lines at a large abattoir (4.96±0.90 log CFU/g). The average pH of the carcasses from both groups was 5.98. *Pseudomonas*, lactic acid bacteria, and yeasts were the main microbial contaminants found on corpses from the small abattoir. On carcasses from the large abattoir, *Brochothrix thermosphacta* was the predominated species. The primary microbial groups on prepacked hind legs were *Pseudomonas*, yeasts, lactic acid bacteria, and *B. thermosphacta*. The mean aerobic mesophilic count was 5.87±1.03 log CFU/g. The same microbial groups predominated on prepackaged complete carcasses (pH 6.37±0.18), which were chilled at 1 to +5° C. The mean aerobic mesophilic count was 6.60±1.18 on these carcasses. Overall, coagulase-positive staphylococci, *Escherichia coli*, psychrotrophic clostridia, enterobacteriaceae, coliforms, and moulds were detected at low levels. In a continued work by the same authors (Rodríguez-Calleja *et al*., 2005), aerobic plate count, psychrotrophic flora, *Pseudomonas* species, *B. thermosphacta*, lactic acid bacteria, Enterobacteriaceae, and yeasts had initial levels (log cfu/g) of 4.76±0.31, 4.81±0.81, 3.39±1.12, 2.01±0.92, 2.76±0.51, 0.49±0.45, and 3.46±0.32. At the end of the shelf life, pseudomonads—the majority of which were fluorescent—and, to a lesser extent, *B. thermosphacta* and yeasts, developed more quickly than the other microorganisms. Carcasses spoiled when the average aerobic plate count, psychrotrophic, and pseudomonad counts were around 8 log cfu/g, with a 6.8-day shelf life. After 4 days, several dark firm and dry (DFD)-like rabbit carcasses with higher pH and lower extract-release volume values but with comparable microbial loads to the normal meat however, with a putrid smell, particularly after 4 days. Besides, 27 rabbit meat packages from supermarkets and 24 rabbit carcasses from two slaughterhouses in Spain were bacteriologically examined. In addition to cultivating techniques, PCR was used to examine related virulence genes in questionable isolates and samples. There was no evidence of *Salmonella* spp., or *E. coli* O157:H7. The virulence-associated genes *inv*A, *stx1*, and *stx2* were absent from all samples. Two carcasses from one abattoir (3.9%) had *Y. enterocolitica* (*yst*) and tested positive for the *yst* gene. However, no viable *Y. enterocolitica* cells were found in these samples. Seven samples (13.7%) contained *Listeria* spp. They contained *Listeria seeligeri*, *Listeria ivanovii*, and *Listeria innocua*, and three of them tested positive for the hly and iap genes (*Listeria monocytogenes* hly+/iap+). Although about 90% of the samples tested positive for the *aer*A and/or *hly*A genes, the contamination rate for detectable motile Aeromonas spp. (average count, 1.77±0.62 log CFU/g) was 35.3%. *Aer*A+/*hly*A+ was found in the majority of aeromonad isolates. Additionally, the two biovars of Aeromonas veronii as well as Aeromonas caviae, Aeromonas popoffii, Aeromonas schubertii, and others were isolated. 52.9% of samples were positive for *S. aureus* contamination (average count, 1.37±0.79 log CFU/g). Two of the 27 *S. aureus* isolates had Staphylococcal enterotoxin B (seb) genes, and two had staphylococcal enterotoxin C genes (sec). *Sea, Seb, Sec, Sed*, and *See* tests were negative for the remaining isolates.

The microbial quality of rabbit meat was also reviewed by Hernández (2008) who mentioned that different feeding regimens may also have an impact on the microbial ecology of rabbit meat; some feed ingredients may have a particular impact on how quickly various microbial groups thrive. According to research by Vannini *et al*. (2003), adding whole linseeds to one's diet can reduce the rate of growth of various microbial groups (aside from psychrotrophic bacteria) and lengthen the shelf life of meat. A high percentage of dried alfalfa meal in the di*et al*so appears to have an inhibitory effect on microbial growth in products made from rabbit meat (Vannini *et al*., 2002).

The residual blood content and storage stability of rabbit meat were studied to compare the effects of halal slaughter without stunning against gas stunning followed by bleeding. Eighty male New Zealand white rabbits were split into two groups of forty each and either gas stun killed (GK) or slaughtered according to halal law (HS). Exsanguination's blood loss was assessed in terms of volume. By measuring the amount of hemoglobin present in the *Longissimus lumborum* (LL) muscle, residual blood was further quantified. Microbiological testing and assessing lipid oxidation in terms of thiobarbituric acid reactive compounds were used to assess the meat's storage stability (TBARS). HS caused a lot more blood to be lost than GK did. When compared to GK, HS had considerably less residual hemoglobin in LL muscle. At 0, 1, and 3 days after death, the manner of slaughter had no impact on the lipid oxidation of rabbit flesh. However, significant differences were identified at 5 and 8 days of storage at 4°C, with meat from the GK group showing considerably greater levels of MDA than that from HS. At day 3, *Pseudomonas aeroginosa* and *E. coli* grew more rapidly in the GK group than in the *B. thermosphacta* group, although total aerobic counts were unaffected by the mode of slaughter. All studied microorganisms' bacterial counts were impacted by the technique of slaughter at days 5 and 7 postmortem, with GK showing much faster development than HS. The manner of slaughter can have an impact on how well rabbit meat keeps, and HS may be preferable to GK due to high bleed out (Nakyinsige *et al*., 2014).

The shelf-life of rabbit loins was examined at days 1, 4, and 10 of chilled storage to compare the effects of two dietary lipid sources (sunflower vs. linseed oil) and three packaging techniques (PVC film - BAG, modified atmosphere CO2 20% + 80% O2, and vacuum - VAC) in a study conducted in Hungary. Throughout the shelf-life testing, linseed oil had no negative effects on the physical, sensory, or microbiological quality of the rabbit meat. Despite the diverse dietary oil sources and consequently varying susceptibilities to oxidation, the three packaging techniques were all equally effective in preserving the physical and sensory quality of the rabbit meat. The analysis of the microbiological count at day 4 of shelf-life revealed that MAP and VAC were superior to BAG at maintaining the sanitary quality of the rabbit meat. The microbiological quality of the rabbit meat samples from MAP and VAC was the same at day 10 (Cullere *et al*., 2018).

An experimental study was conducted in Canada and assessed the impact of adding plant extracts (onion, cranberry) and a commercial essential oil product (XtractTM) to feed on the quality of the meat from rabbits. A control ration or a diet supplemented with onion extract (500 or 1000 ppm), cranberry extracts (500 ppm), and essential oil product (100 ppm) alone or in combination were given to each of five groups of 48 weaned Grimaud female rabbits. Whole hind legs that were kept at 4 °C in both aerobic and anaerobic settings had their microbiological quality assessed. The experimental groups' growth performances, feed intake, and meat composition and quality were comparable. However, all of the augmented ones had considerably increased meat total phenolic content. The effect of dietary supplements was noted, and under anaerobic conditions, microbial control was significantly improved, particularly for total aerobic mesophilic counts, presumed *Pseudomonas* spp., and Enterobacteriaceae. Overall, treatment with onion extract (500 ppm) more successfully reduced microbial growth (Koné *et al*., 2019).

In a study conducted in Italy, 42 New Zealand white rabbits were assigned into two groups, a commercial diet-receiving control group and group that received a diet with goji berries (3% w/w) (n = 21 per group). After the rabbits were sacrificed, the impact of nutritional supplementation on the microbiological, physico-chemical, and sensory traits was assessed at 6 hours postmortem (day 0), 4 days, and 10 days after being stored in the refrigerator. Microbiological results showed that the supplementation had a significant impact on the beneficial *Lactobacillus* spp. prevalence, indeed the goji group had higher means on day 0 and on day 4 than the control group. Overall, these results indicated that the goji berries inclusion in the rabbit diet could represent a valuable strategy to improve quality and sensory traits of meat (Castrica *et al*., 2020).

The effects of adding garlic (*Allium sativum* L.) powder, ramsons (*Allium ursinum* L.) powder, or combining the two on the microbiological quality of rabbit meat burgers were assessed in a recent study carried out in Poland. The development of Enterobacteriacea, *Pseudomonas* spp., lactic acid bacteria, or all aerobic psychrotrophic bacteria was unaffected by the additions that were examined. On the seventh day of storage, however, the numbers of all identified bacteria increased. However, in order to increase the shelf life and eating quality of rabbit meat burgers, garlic powder and ramsons powder can be added (Śmiecińska *et al*., 2022).

CONCLUSION

Rabbit meat and offal are emerging sources of high-quality animal protein with high nutritive value for other nutrients. However, rabbit meat is also regarded as a potential source of food poisoning organisms that lead to several adverse health effects and decrease the shelf life of the rabbit meat. Interestingly, several reports showed that microbial quality and sensory characteristics of the rabbit meat can be improved by physical methods such as irradiation, or vacuum packaging, or by the addition of some natural additives such as onion, garlic, and cranberry.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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