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Microbial Contamination and Adulteration Detection of Meat Products in Egypt

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ABSTRACT

Meat products as rich sources of several nutrients are easily contaminated by microorganisms, which are widely predominant in the environment. Moreover, meat products could also be adulterated with equine, pig, chicken, and mouse meat, and their existence is risky for consumers. A total of 140 meat product samples (minced beef meat, beef burger, sausage, beef luncheon, frankfurter, kofta, and bastirma; 20 samples from each product) were gathered from various supermarkets in Cairo governorate, Egypt. Those samples were subjected to bacteriological and mycological examination together with a novel multiplex PCR method to detect bovine, donkey, horse, pork, chicken, and mouse species in the processed meat in a single reaction step. The results revealed that minced meat had the highest total colony count and *Staphylococcus aureus* counts were the highest in sausage samples. *Escherichia coli* mean values were the highest in luncheon samples and minced meat indicated the highest *Salmonella* count. However, beef burger counts were the highest for both yeast and mold count. For multiplex PCR results, only 16.4% of meat products samples were negative for bovine species. Moreover, 88.5% and 9.2% were respectively positive to chicken and mouse speciesand negative to equine and pig species. Thus, microbial contamination reported in the current study could raise attention toward the implementation of food safety standards in both factories and markets. Moreover, and multiplex PCR-based assay executed in the current study is suggested since it could afford sensitive and specific detection of mitochondrial cytochrome-b (mtcyt-b) DNA in processed meat products samples to detect and prevent troubles related to wellbeing and safety.

Keywords: Adulteration, Bacteriological, Meat products, Multiplex PCR, Mycological

INTRODUCTION

Meat and meat products are nutritive food for human beings as they are rich in protein, basic amino acids, vitamins, fats, minerals, and other nutritive constituents (Biesalski, 2005). However, meat products can serve as a suitable culture medium for the growth of different organisms because of high moisture, high consistent of nitrogenous compounds, great supply of minerals, a few fermentable carbohydrates as glycogen, and the ideal pH that support the growth of most microbes (Alahakoon et al., 2015).

Raw meat contains different pathogenic organisms, such as *Salmonella* spp. *Escherichia coli* (*E. coli*), and *Staphylococcus aureus* (*S. aureus*). This makes raw meat a real danger to human health since it can easily cause food-borne diseases as a result of bad handling and improper control measures against those pathogens (Nørrung et al., 2009). *Staphylococcus aureus* is an important source of worldwide food intoxication. Different types of foods may be contaminated by this microorganism and develop numerous forms of enterotoxins due to inappropriate processing of meat products (Balaban and Rasooly, 2000).

Mycotic contamination of meat products may originate from meat or bad quality flavoring materials, particularly spices, and improper hygienic procedures during various processing steps and storage of the products (Gourama and Bullerman, 1995). Fungal contamination of meat products is considered a major public health hazard as fungi can cause three different types of illnesses, namely mycosis, mycotoxicosis, and allergy (Abuzaid et al., 2020).

Accomplishing food safety is a worldwide health objective and food-borne manifestations that have attracted major attention in global health. Hence, the determination of microbial pathogens in food is the key in the identification and prevention of problems related to wellbeing and safety Gokulakrishnan and Vergis (2015). False or inadvertent mislabeling of meat products, which can not be distinguished using conventional strategies is still predominant over the world. Some individuals may not like to consume the meat of equine and pork due to ethical, religious, or compassionate reasons. So, these clusters of consumers demand methods to detect types of meat (equine, pork, chicken, and mouse) in the food (Haunshi et al., 2009).

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The species of meat used in prepared, cooked, or compounded blends is not continually plausible to be distinguished by schedule examination. However, denaturation of meat proteins during heat treatment or any other technological processes and variation of protein compositions, even in the same species, reduce the chance of success for these methods. Besides, these strategies may be insufficient to segregate between species which are in near connection and are not reasonable for schedule utilize, as the confinement of species-specific proteins is troublesome and time-expending (Kesmen et al., 2010). DNA analysis is now a famous approach for meat species identification. Nowadays, DNA is preferred for species identification due to its great constancy, compared to proteins. Applications of polymerase chain reaction (PCR) have been augmented because of their easiness, speed, and specificity (Kesmen et al., 2007). Multiplex-PCR is an effective technique that can instantaneously amplify the template mix, diminish the recognition charge, and eliminate the failure of single PCR of detecting only one meat species at a time (Abuelnaga et al., 2021).

The current study aimed to detect microbial load and identify foodborne pathogens in different meat product samples to prevent manifestations related to health and safety. Moreover, it investigated the application of a novel multiplex PCR (M-PCR) as a sensitive and specific method to detect adulteration in meat products sold in different supermarkets in Cairo, Egypt with equine, pig, chicken, and mouse meat.

MATERIALS AND METHODS

Ethical approval

The current study was conducted on meat product specimens and no invasive procedures were performed on animals, no ethical approval was required.

Samples

A total of 140 meat product samples included 20 samples from each product of minced beef meat, beef burger, sausage, beef luncheon, frankfurter, kofta, and bastirma were gathered from different supermarkets in Cairo area, Egypt from June 2020 until June 2021. The samples were microbiologically examined (identification and counting of microbes) and also underwent multiplex PCR for the detection of species adulteration. Meat specimens from different chosen species (bovine, equines, pig, chicken, and mouse) were utilized as a positive control when testing the meat product specimens. Meat product samples which were negative to bovine Spp. or positive to the other tested species were considered adulterated.

Preparation of samples for microbiological examinations

To begin 10 g from each specimen were blended with 90 ml of 0.1% sterile peptone water and were mixed for 2-4 minutes and were left to stand for approximately 5 minutes at room temperature; at that point 10 times serial dilutions were executed for counting microbes under complete aseptic condition (Datta et al., 2012).

Bacteriological examinations of meat products

The total bacterial count was done by utilizing a standard plate count agar medium. In this regard, 1 ml from each of the already prepared serial dilutions (10^2 to 10^6) was inoculated in duplicate plates under aseptic circumstances and they were incubated at 37˚C for one day. Later, the counted colonies were calculated as cfu/g and recorded (Datta et al., 2012).

Determination of total *Escherichia coli, Staphylococcus aureus,* and *Salmonella* counts

Total *E. coli*, *S. aureus*, and *Salmonella* counts were performed. To this end, 1 ml from each of the previously prepared serial dilutions was inoculated into duplicate plates of E.M.B, Mannitol salt, *Salmonella Shigella* agar plates and were kept at 37ºC for a day. Colonies were counted and these colonies were identified using API 20E kit (Bio Merieux) and the identification was done according to the manufacturer's directions in order to detect the biochemical profile of the isolated microbes (Datta et al., 2012)

Serological identification

The somatic (O) antigen of *E. coli* was detected by slide agglutination test as described by Edwards and Ewing (1972), and Flagellar (H) antigen serotyping was performed according to Davies and Wray (1997). Anti-O-sera was purchased from DENKA SEIKEN CO LTD Tokyo, Japan. *Salmonella spp*. was serotyped as reported by Bale et al. (2007).

Mycological examination of meat products

Pour plating

At the stage, 1 ml of the prepared dilutions (10^2 to 10^6) was added into a petri dish in duplicate. Pour into each Petri dish 10 to 20 ml molten SDA (cooled to 42-45ºC). Blend the media and dilutions by whirling clockwise and anti-clockwise and permit solidification (Soliman et al., 2019)

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Isolation and identification of fungi

Inoculated Petri dishes were left to solidify at ambient temperature. The plates were inverted to anticipate spreaders and incubated at 25ºC for 3-5 days. The yeast colonies, which were in a dull white, creamy, yellow, pink, regular, and irregular shape, were counted independently using a colony counter and yeast count/gram was calculated and recorded, and for mold, the plates were incubated at 25ºC for 5-7 days at an inverted position. During the incubation period, the plates were inspected daily for star-shaped mold growth, and colonies were counted and recorded (APHA, 1992). Identification of isolated molds was performed according to Samson et al. (2010).

Multiplex polymerase chain reaction

DNA extraction from meat samples

DNA was extracted from meat samples using the MagMAX™ CORE Nucleic Acid Purification Kit (Cat. No. A32700, Thermo Fisher Scientific Inc., USA) Following manual instructions with some modifications where 25 mg of tissue samples are used and DNA was eluted in 50 µL of the elution buffer included in the kit.

Primer design

Species-specific PCR primers targeting mitochondrial Cytochrome-b gene of bovine, equines (donkey and horse), pig, and chicken, and the 12S ribosomal RNA mitochondrial gene of the mouse have been developed as shown in Table 1. All primers were obtained from Vivantis Technologies, Malaysia.

Multiplex Polymerase Chain Reaction

The 25µl reaction mixture was prepared using 12.5µl of 2x COSMO PCR RED Master Mix (Cat. W1020300X, Willofort Co., UK), 0.5 µL (20 pmol) of each primer, and 1 µL of target DNA. The M-PCR cycles began with Initial Denaturation at 95°C for 2 minutes, followed by 39 cycles of denaturation at 95°C for 20 seconds, and annealing for 30 sec at 56°C (Table 1). After that extension was at 72°C for 45 seconds and a single final extension was at 72°C for 10 minutes (GS-96 gradient thermocycler, Hercuvan, Malaysia). Electrophoresis was performed on agarose gel (1.5%) at 100V for 1h with the use of a 50 bp ladder plus (Cat No. M7115 BIOMATIK, Canada) and examined using InGenius3 gel documentation system (Syngene, UK).

Statistical analysis

Data were analyzed descriptively (mean, maximum, maximum, and standard error) using SPSS 14.

Table 1. The primer pairs used in specific PCR identification of bovine, Donkey, pig, chicken, and mouse meats

Species	Sequence (5´-3´)	PCR product	Anneal. temp.	Reference
Bovine	GCCATATACTCTCCTTGGTGACA GTAGGCTTGGGAATAGTACGA	271bp	56°C	Ilhak and Arslan (2007)
Donkey	ATCCTACTAACTATAGCCGTGCTA CTATCCGACACACCCAGAAGTAAAG	145bp	56°C	Kesmen et al. (2007)
Horse	CTATCCGACACACCCAGAAGTAAAG GATGCTGGGAAATATGATGATCAGA	153bp	56°C	Kesmen et al. (2010)
Pig	CCCAGCCCCCTCAAACATCTCA ATGTACGGCTGCGAGGGCGGTAA	525bp	56°C	Khairalla et al. (2005)
Chicken	CTCGCCCTACTTGCCTTCC TAGGACGCAACGCAGGTGT	256bp	56°C	Haunshi et al. (2009)
Rat and Mouse	AATCCAACTTATATGTGAAAATTCATTGT TGGGTCTTAGCTATCGTCGATCAT	96bp	56°C	Martín et al. (2007)

RESULTS

Meat products samples were microbiologically tested and the results were presented as mean values ± standard error (SE) counts /g for total colony count (TCC), *S. aureus*, *E.coli*, and *Salmonella* (Table 2). Table 3 shows the incidence of *S. aureus*, *E.coli*, and *Salmonella* in meat product samples. *Salmonella spp* were serologically identified as *S. Typhimurium*, *S.Kentuky*, *S. Enteritidis*, *S. Blegdam*, and *S. Agama*. The distribution of those serovars in different meat product samples is presented in Table 4. *Escherichia coli* was serologically identified as *O 26, O 126, O 111, O158, O 146*, and untyped *E-coli*. The presence of different serovars in various meat product specimens is presented in Table 5.

The mycological examination of meat products (minced beef meat, beef burger, sausage, beef luncheon, frankfurter, kofta, and bastirma) revealed that the incidence of yeast contamination was 80% , 75%, 55%, 60%, 65%, 60%, and 50%, respectively, and 50%, 65%, 77%, 60%, 70%, 50%,80%, for molds, respectively. Fungal counts for yeast and molds are presented in Table 6.

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Multiplex PCR results, the identification of bovine, donkey, horse, pig, chicken, and mouse tissues in the meat products, specificity of the species-specific primers, and peak PCR conditions were intended. The primers provided unique species-specific fragments of 271, 145, 153, 525, 256, and 96 bp, respectively (Figures 1 and 2). In the present study, molecular examination of meat product samples revealed that only 16.4% of meat products samples were negative to bovine Spp. Moreover, 88.5% and 9.2% were positive to chicken and mouse Spp. respectively, and negative to equine and pig Spp. as shown in Table 7.

Table 2. Bacterial counts of different meat products in Egypt during 2020-2021

Samples	TCC	*Staphylococcus aureus*	*Escherichia coli*	*Salmonella*
Minced beef meat	$1.8\times10^6 \pm 6.6\times10^5$	$1.1\times10^3 \pm 5.6\times10^2$	$9.7\times10^2 \pm 3.8\times10^2$	$4.8\times10^2 \pm 1\times10^2$
Beef burger	$4.1\times10^5 \pm 2.8\times10^5$	$6.8\times10^2 \pm 1.7\times10^2$	$1.5\times10^2 \pm 6.4\times10$	$2\times10^2 \pm 4.4\times10$
Sausage	$1\times10^6 \pm 4.2\times10^5$	$1.2\times10^3 \pm 3.7\times10^2$	$8.1\times10^2 \pm 2.6\times10$	$4.3\times10^2 \pm 1\times10^2$
Beef luncheon	$8.6\times10^5 \pm 3.7\times10^5$	$8.2\times10^2 \pm 3.6\times10^2$	$1.3\times10^3 \pm 4\times10^2$	$2.2\times10^2 \pm 7\times10$
Frankfurter	$1.7\times10^4 \pm 8\times10^3$	$2.4\times10^2 \pm 6\times10$	$2\times10^2 \pm 5.7\times10$	$8.1\times10 \pm 0.5\times10$
Kofta	$6.1\times10^5 \pm 3.1\times10^5$	$4.4\times10^2 \pm 9.5\times10$	$4.5\times10^2 \pm 1\times10^2$	$2.7\times10^2 \pm 10\times10^2$
Bastirma	$2.3\times10^4 \pm 8.5\times10^3$	$3.9\times10^2 \pm 1\times10$	$3.4\times10^2 \pm 9.9\times10$	$5.5\times10 \pm 1.7\times10$

TCC: Total colony count

Table 3. Incidence of *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella* in meat product samples in Egypt during 2020-2021

Samples	*Staphylococcus aureus*		*E.coli*		*Salmonella*	
	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*
Minced beef meat	7	35	9	45	4	20
Beef burger	5	25	2	10	3	15
Sausage	8	40	6	30	4	20
Beef luncheon	6	30	11	55	3	15
Frankfurter	2	10	4	20	2	10
Kofta	4	20	5	25	3	15
Bastirma	3	15	4	20	2	10
Total (140)	35	25**	41	29.3**	21	15**

* Twenty samples of each meat product were examined the percent was calculated according to the number of each meat product (n = 20). ** The percent was calculated according to the number of all meat product samples (140). No. of +ve: Number of positive.

Table 4. *Salmonella* serovars isolated from meat products in Egypt during 2020-2021

Meat product samples	*Salmonella Typhimurium*		*Salmonella Kentuky*		*Salmonella Enteritidis*		*Salmonella Blegdam*		*Salmonella Agama*	
	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*
Minced beef meat	2	50	0	0	1	25	1	25	0	0
Beef burger	1	33.3	1	33.3	1	33.3	0	0	0	0
Sausage	2	50	1	25	0	0	1	25	0	0
Beef luncheon	2	66.6	1	33.3	0	0	0	0	0	0
Frankfurter	0	0	1	50	0	0	0	0	1	50
Kofta	0	0	1	33.3	1	33.3	0	0	1	33.3
Bastirma	0	0	1	50	1	50	0	0	0	0

* The percent was calculated according to the number of each serovar of meat product samples.

Table 5. *Escherichia coli* serovars isolated from meat products in Egypt during 2020-2021

Meat product samples	*O 26*		*O 126*		*O 111*		*O158*		*O 146*		*O 114*		untyped	
	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*	No. of +ve	%*
Minced beef meat	2	22.22	1	11.11	2	22.22	1	11.1	1	11.11	1	11.1	1	11.11
Beef burger	1	50	0	0	0	0	1	50	0	0	0	0	0	0
Sausage	2	33.3	1	16.7	1	16.7	0	0	0	0	2	33.3	0	0
Beef luncheon	2	18.8	2	18.18	1	9.1	1	9.1	2	18.18	1	9.1	2	18.18
Frankfurter	1	25	1	25	2	50	0	0	0	0	0	0	0	0
Kofta	1	20	2	40	0	0	0	0	2	40	0	0	0	0
Bastirma	1	25	0	0	0	0	1	25	0	0	1	25	1	25

*The percent was calculated according to the number of each serotype for each meat product

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Table 6. Total yeast and mold counts in different meat product samples in Egypt during 2020-2021

The examined samples	Total yeast (count /gm)	Total molds (count /gm)
Minced beef meat	$1.3\times10^3 \pm 1.4\times10^2$	$2.5\times10^2 \pm 1.6\times10^2$
Beef burger	$1.4\times10^3 \pm 9\times10$	$1.3\times10^3 \pm 9.2\times10^2$
Sausage	$4.7\times10^2 \pm 4.1\times10^2$	$3.4\times10^2 \pm 2.1\times10^2$
Beef luncheon	$1.6\times10^3 \pm 1\times10^3$	$2.3\times10^2 \pm 1.3\times10^2$
Frankfurter	$1.1\times10^2 \pm 1.8\times10$	$0.6\times10 \pm 0.2\times10$
Kofta	$1.8\times10^3 \pm 1.3\times10^3$	$0.5\times10 \pm 0.1\times10$
Bastirma	$4\times10 \pm 0.5\times10$	$0.4\times10 \pm 0.07\times10$

The results were expressed as mean ± Standard Error

Table 7. Number and percentage of adulterated meat samples

Sample	Bovine (-ve)		Equine (+ve)		Pig (+ve)		Chicken (+ve)		Mouse (+ve)	
	No	%*	No	%*	No	0%*	No	%*	No	%*
Minced beef meat	10	50%	0	0%	0	0%	20	100%	3	15%
Beef burger	5	25%	0	0%	0	0%	20	100%	0	0%
Sausage	8	40 %	0	0%	0	0%	18	90%	4	20%
Beef luncheon	0	0%	0	0%	0	0%	18	90%	1	5%
Frankfurter	0	0%	0	0%	0	0%	16	80%	0	%
Kofta	0	0%	0	0%	0	0%	19	95%	5	25%
Bastirma	0	0%	0	0%	0	0%	13	65%	0	0%
Total	23/140	**16.4%****	0/140	**0%****	0/140	**0%****	124/140	**88.5%****	13/1140	**9.2%****

*: Twenty samples of each meat product were examined and the percentage was calculated according to the number of each meat product (n = 20). **: The percent was calculated according to the number of all meat product samples (n=140). **+ve**: Positive means adulterated

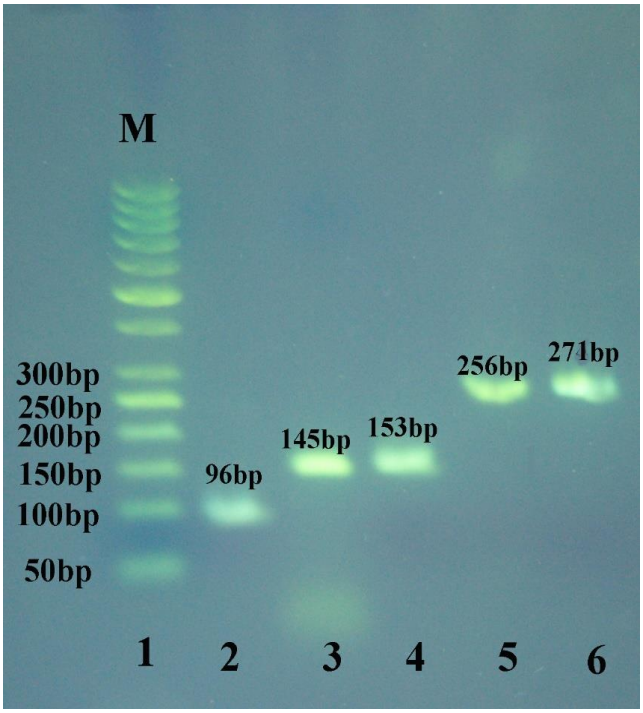

Figure 1. The PCR product of control meat (mouse, donkey, horse, chicken, and bovine meat) amplified with species-specific primers. **1:** Molecular marker (50 bp), **2:** Mouse meat; 3: Donkey meat; 4: Horse meat; 5: Chicken meat; 6: Bovine meat.

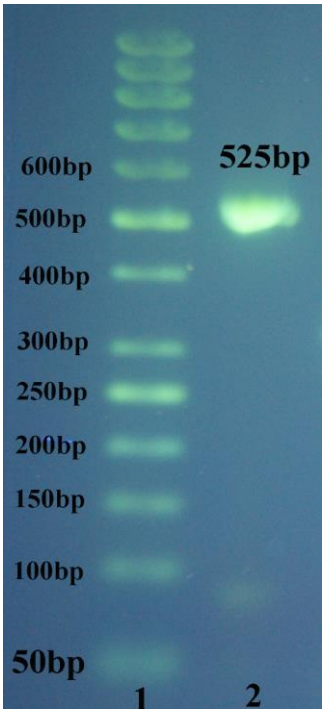

Figure 2. The PCR product of control meat (pig meat) amplified with pig-specific primers. **1:** Molecular marker (50 bp), **2:** Pig meat.

DISCUSSION

Meat is favored by millions of people worldwide as a major supply of animal protein but it is considered a favorable medium for the growth of different microorganisms, so it acts as a hygienic risk problem to the consumer (Elsayed et al., 2018). Meat and meat products are constituted as major causes of most known food poisoning outbreaks. Therefore, it is crucial to use microbiological criteria to detect the quality of those products (Abuzaid et al., 2020).

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As indicated in Table 2, the total colony count results obtained in the current study were similar to those reported by Erdem et al. (2014) 9×10^6 CFU/g in minced meat in Istanbul. Shaltout et al. (2016) declared that the mean counts in luncheon, minced meat, kofta, and sausage were 4.2 ± 0.1, 4.8 ± 0.1, 5.8 ± 0.1, and 6.1 ± 0.1 log CFU/g in Egypt, respectively, Abuzaid et al. (2020) calculated the mean of total bacterial counts of 80 types of meat products in Egypt and the counts were $11 \times 10^6 \pm 5.4 \times 10^6$, and $2.04 \times 10^6 \pm 0.12 \times 10^6$ cfu/g for sausages and Kofta, respectively. However, lower counts were obtained by Salem et al. (2010) as they found that the total bacterial count was 5.61×10^5 CFU/g in minced meat in Egypt, and also Mousa et al. (2014) obtained lower results as they stated that the total aerobic bacterial counts were 8.20×10^2, 6.29×10^2, $5.4 \times 10^{2,}$ and 8.28×10^2 in the beef burger, luncheon, bastirma, and sausage, respectively in Egypt. Higher results were recorded by Gönülalan and Köse (2003) that was 5.3×10^9 in minced meat of China and Ahmed (2009) who reported that the mean value of APC was 1.26×10^6 for kofta and $11 \times 10^6 \pm 5.4 \times 10^6$ for Sausage in Egypt.

The total colony count results of *S. aureus* were similar to those obtained in Egypt by Morshdy et al. (2013) as *S. aureus* count of minced meat was 4.3×10^2/g and also Shaltout et al. (2016) found that *S. aureus* counts were 2.5 ± 0.1, 2.2 ± 0.1, 2.5 ± 0.2, and 2.6 ± 0.1 in luncheon, minced meat, kofta, and sausage, respectively. Higher values were obtained in Jordan by Al- Kour (2001) 4.13×10^3/g in minced meat and Elmossalami (2003) 1.8×10^3/g in sausages in Egypt.

Regarding the Coliform count presented in Table 2, the results were nearly similar to those obtained in Egypt by Salem et al. (2010) as 5.12×10^3 CFU/g in minced meat in Egypt and by Shaltout et al. (2016) as 2.6 ± 0.1, 3.1 ± 0.1, 2.6 ± 0.1 and 2.9 ± 0.01 log CFU/g in luncheon, minced meat, kofta, and sausage, respectively. Higher results were obtained by Erdem et al. (2014) in Istanbul as they recorded a mean count of 4.5×10^7 cfu/g in minced meat and Abuzaid et al. (2020) examined 80 specimens of meat products in Egypt for coliforms and mean counts were $6.7 \times 10^3 \pm 0.3 \times 10^3$ and $1.2 \times 10^3 \pm 0.16 \times 10^3$ for sausages and kofta, respectively. Lower results were obtained by Mousa et al. (2014) which were 2.92×10^2, 3.5×10^2, 4.19×10^2, and 7.64×10^2 in the beef burger, luncheon, bastirma, and sausage, respectively, in Egypt.

The incidence of *S. aureus*, *E. coli*, and *Salmonella* in meat product samples is shown in Table 3. Similar results were obtained by Ragab et al. (2016) as they detected *E. coli* in 50 % of the examined minced meat samples and 30% of both kofta and beef burger samples in Egypt. Mousa et al. (2014) also recorded the incidence of *S. aureus* was 68%, 80%, 60%, and 88% in beef burger, luncheon, bastirma, and sausage, respectively, in Egypt. Higher results were obtained in Argentina by Stagnitta et al. (2006) as they isolated *E. coli* from 62.2%, 56%, and 24% in sausages, hamburgers, and minced beef, respectively. Variable results were obtained by Mousa et al. (2014) in Egypt as they stated that the incidence of *Salmonella* spp. was 20%, 26%, 6%, and 40% in the beef burger, luncheon, bastirma, and sausage, respectively.

In the present study, *Salmonella Typhimurium* was the most predominant servoar as clearly shown in Table 4 and Moawad et al. (2017) in Egypt obtained similar results indicating *Salmonella Typhimurium* as the most isolated serovar from both fresh and frozen beef meat.

Escherichia coli was serologically identified as *O26, O126, O111, O158, O146,* and untyped *E. coli,* and the distribution of those serovars in different meat product samples was shown in Table 5. *E. coli O26* was the most prevalent servoar in the current study but Moawad et al. (2017) in Egypt identified *E. coli* type *O158* mainly in beef meat.

The defilement of meat and meat products with various species of fungi and aflatoxins is considered a major public health hazard due to the dynamic increase in the utilization rates of these products. The exposure of meat and meat products to mycotic defilement due to the lack of hygienic conditions during slaughtering, processing, and storage, as well as the added spices and some food additives, constituted the principal source of toxigenic molds and mycotoxins leading to either food deterioration or foodborne mycotoxicosis (Al-Yazeed et al., 2015).

In the current study, the mycological examination revealed that the incidence of yeast contamination was 80%, 75%, 55%, 60%, 65%, 60%,50% in minced beef, beef burger, sausage, beef luncheon, frankfurter, kofta, and bastirma, respectively. Similar results were also obtained in Egypt by Soliman et al. (2019) as they revealed that the recovery of yeasts from luncheon and hamburger were 65% and 77.5%, respectively. However, Ismail et al. (2013) obtained lower results as they isolated the yeasts from only 28% of the examined Luncheon samples.

For molds, the incidence of molds in minced beef meat, beef burger, sausage, beef luncheon, frankfurter, kofta, and bastirma were 50%, 65%, 77%, 60%, 70%, 50%, 80%, respectively, and similar results in Egypt were obtained by Al-Yazeed et al. (2015) as they mycologically examined 200 meat and meat products samples (50 of frozen meat specimens and 30 of each of minced meat, bastirma, hamburger, luncheon, and sausage) and found that the highest incidence of molds contamination was 86.66% in bastirma, and sausage samples, followed by 66.66% in hamburger, 60% in luncheon, 50% in minced meat. Soliman et al. (2019) also stated that the isolation of molds from luncheon and hamburger were 60% and 67.5%, respectively. Abd El-Tawab et al. (2020) assured that molds were isolated from 50% of the examined minced beef specimens, and Abuzaid et al. (2020) also found that the incidence of mold in the examined

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samples of Kofta and sausage were 62.5% and 82.5%, respectively. However, the incidence was lower than the incidence of mold in kofta reported by Hussein (2008) as 93.3%. Higher results were also obtained by Ismail et al. (2013) as they isolated the molds from 92% of the examined luncheon samples and also Abd El-Tawab et al. (2020) revealed that molds were isolated from 80% of the examined sausage samples. Higher results were also obtained in Argentina by Stagnitta et al. (2006) as the counts of molds and yeasts were detected in 100% of the 515 samples.

In the current study, the mycological results of total yeast and mold count (mean ± SE) in different meat product samples are shown in Table 6. In Egypt, Soliman et al. (2019) obtained similar results as they reported the mean of total yeast count/gm ± standard error for luncheon and beef burger as $2.9\ 10^3 \pm 7.2 \times 10^2$ and $4.3 \times 10^3 \pm 1.1 \times 10^3$, respectively. Abuzaid et al. (2020) examined 80 specimens of meat products represented by sausages and Kofta and the total yeast count was $0.52 \times 10^3 \pm 0.08 \times 10^3$ and $0.47 \times 10^3 \pm 0.07 \times 10^3$, respectively.

For molds, Elsayed et al. (2018) obtained similar results and found that the mean mold count was $1.3 \times 10^2 \pm 2.1 \times 10$ cfu/g, $2.8 \times 10^2 \pm 4.3 \times 10$ cfu/g, and $6.9 \times 10^2 \pm 1.2 \times 10^2$ cfu/g in luncheon, minced meat, and sausage in Egypt, respectively. A higher mold count was obtained by Abuzaid et al. (2020) as they examined 80 specimens of meat products, including sausages and Kofta with the total mold count of $1.1 \times 10^3 \pm 0.14 \times 10^3$ and $1.4 \times 10^3 \pm 0.27 \times 10^3$ in Egypt, respectively. Higher counts were obtained in Libya by Naas et al. (2009), as they mentioned that examined fresh beef sausage samples had a mold count of $2.3 \times 10^6 \pm 2.7 \times 10^5$ cfu/g. However, lower results were recorded by Mousa et al. (2014) as the total fungal counts were 4.7×10^2, 1.21×10^2, 1.22×10^2, and 1×10^2 in beef burger, luncheon, bastirma, and sausage in Egypt, respectively.

The present paper describes the development and application of a novel multiplex PCR method to detect bovine, donkey, horse, pork, chicken, and mouse species in processed meat in a single reaction step as described by Xu et al. (2008). In the Egyptian markets, the addition of an undeclared meat species (such as chicken in beef products) and/ or unacceptable meat type (pork and donkey, Zahran and Hagag, 2015; Yacoub and Sadek, 2017) or the replacement of one valuable species by another inexpensive one are common examples of meat adulteration (Ahmed et al., 2011; Zahran and Hagag, 2015).

The results of the current study indicated that 88.5% of meat samples (124/140) were positive for chicken spp. (Table 7). The current findings showed a high incidence of species fraudulence, particularly, 100% of minced beef meat and beef burger and 95% of kofta exhibited poultry contaminants. In Egypt, poultry meat is cheaper than beef, which may cause such adulteration. This instance can be considered a distinctive illustration of fraudulent replacement of a high value and more expensive meat species by inferior, lower value, and cheaper species, indicating an economic fraud (Abuelnaga et al., 2021).

The obtained values of the current study were higher than those reported by Abd El-Aziz et al. (2018) indicating 78% of kofta and hawawshy samples were found to be adulterated with chicken DNA. Moreover, this also was higher than those of Mehdizadeh et al. (2014) and Omran et al. (2019) that demonstrated that 94.4% of all hamburgers and 87.5% of all examined commercial meat products contained undeclared chicken meat. Away from price, religious customs are one of the distinguished subjects that should be taken into account. For example, it is forbidden for Muslims to consume the flesh of pork and its derivatives. Something else, some permitted meat is not alluring for Egyptian customers, as donkey and horse meat, that may be sold without any offered costs, and thus there's a critical chance of blending them in Egyptian nourishments (Ali et al., 2015). The adulteration rate with donkey meat in the current study (0%) was parallel to that of El-Shazly et al. (2016) and less than that reported value in Egypt by Abd El-Nasser et al. (2010) in minced meat (7%) and sausage (8%), Zahran and Hagag (2015) in beef meat (5%), Abd El-Razik et al. (2019) in beef meat (6.25%), Omran et al. (2019) in commercial meat products as beef burger, oriental beef sausages, kofta and beef luncheon from various regions of Ubber Egypt (12.5%). In the present work, the result for equine meat was (0%) and this may be due to the strict control on food in Cairo, the Capital of Egypt.

Moreover, the adulteration rate of horse meat in the current study (0%) was less than that reported rates in Egypt by several investigators (El-Shewy, 2007; Abd El-Nasser et al., 2010; Jaayid, 2013), and the adulteration rate of beef meat (2.08%) as reported by Abd El-Razik et al. (2019). The results indicated that all the meat samples were negative to pig spp. which was parallel to the findings of El-Shazly et al. (2016) and Galal-Khallaf (2021) but lower than reported values by Meyer et al. (1996), Partis et al. (2000), and Yosef et al. (2014). Moreover, Abd El-Nasser et al. (2010) found that 35.7% and 41.7% of examined minced meat and sausage samples were adulterated with pork meat. Recently, soybean protein has been extensively used as a substitute for red meat in manufacturing burgers (up to 60%) as soybean has functional features, dietary value, along with its cheap price (Soares et al., 2013). The presence of soybeans constitutes commercial fraud in hamburgers collected from markets in Tehran City, Iran as indicated by the DNA extraction (Tafvizi and Hashemzadegan, 2016).

The findings of the present work also revealed that 50%, 25%, and 40% of minced beef meat, beef burger, and sausage were negative to bovine spp., respectively, although it was labeled as beef meat. These meat samples were supposed to be adulterated with soybeans. The adulteration rate with mouse meat in the current study (9.2%), especially

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in kofta (25%) and sausage (20%), may be linked to the unhygienic measures during the processing steps or with the addition of contaminated soybean with mouse (rat) offal.

CONCLUSION

Although Meat products are rich in various nutritive substances, they can easily be attacked by different microorganisms, which are widely distributed in the environment. Processed meats are more susceptible to microbial contamination during different stages of processing. Hence, it is of utmost importance to screen the microbial quality of meat products to deliver better quality and safety. The highly sensitive, specific, and rapid M-PCR method developed in this work is strongly suggested to be used as a screening assay for adulteration detection and abuses of labeling necessities for meat products as this PCR method is valuable to detect the adulteration in products submitted to denaturing technologies.

DECLARATIONS

Authors' contribution

Azza S. M. Abuelnaga designed the plan of the study, participated in performing the experiments, and analyzed the data. Khaled Abd El-Hamid Abd El-Razik participated in designing the plan of the study, performing the experiments, and writing the manuscript. Mona MH Soliman took part in performing the experiments and writing the manuscript. Hala S. Ibrahim; Mona, M.M. Abd-Elaziz and Amany H. Elgohary performed the experiments and participated in analyzing the data. Riham H. Hedia and Elgabry E. A. participated in analyzing the data and writing the manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethical considerations

Ethical issues (including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) have been checked by the authors.

Consent to publish

The authors agreed to publish the article.

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REFERENCES

Abd El-Aziz DM (2018). Molecular and histological investigation of adulterated ready-to-eat heated meat products with chicken substances. International Food Research Journal, 25(5): 1948-1952. Available at: https://life.aun.edu.eg/veterinary_medicine/ar/node/33675

Abd El-Nasser M, Labieb H, and Doaa MA (2010). Identification of meat species in some meat products in Assiut city. Assiut University Bulletin Environment Research, 13(2):1-12. DOI: https://www.doi.org/10.21608/auber.2010.149277

Abd El-Razik KA, Abuelnaga ASM, Younes AM, Atta NS, Arafa AA, and Kandil MM (2019). Species–specific PCR test for the quick recognition of equine tissue in raw and processed beef meat mixtures. Journal of Food Science and Technology, 39: 166-172. DOI: https://www.doi.org/10.1590/fst.39417

Abd El-Tawab AA, El-Diasty EM, Khater DF, and Al-baaly YM (2020). Mycological identification of some fungi isolated from meat products and spices with molecular identification of some penicillium isolates. Advances in Animal and Veterinary Sciences, 8(2): 124-129. DOI: https://www.doi.org/10.17582/journal.aavs/2020/8.2.124.129

Abuelnaga ASM, Abd El-Razik KA, Atta NS, Hedia RH, Elgabry EA, Soliman MMH, and Marie H (2021). Bacteriological assessment and species specific multiplex-PCR test for differentiation of meat of different animal species. Food Science and Technology, 41(1): 98-104. DOI: https://www.doi.org/10.1590/fst.11520

Abuzaid KEA, Shaltout F, Salem R, and El-Diasty EM (2020). Microbial aspect of some processed meat products with special reference to aflatoxins. Benha Veterinary Medical Journal, 39(2): 24-28. DOI: https://www.doi.org/10.21608/bvmj.2020.44886.1274

Ahmed AME (2009). Impact of temperature abuse on safety of food offered in a university student Restaurant. Master of Veterinary Science (Meat Hygiene), Faculty of Veterinary Medicine , Benha University, Egypt. Available at: http://srv4.eulc.edu.eg/eulc_v5/Libraries/Thesis/BrowseThesisPages.aspx?fn=PublicDrawThesis&BibID=10512063

Ahmed H, El-Nasser MA, Mohammed D, and Mohamed M (2011). Identification of meat species in some raw meat products in Assiut city, Egypt. In Animal hygiene and sustainable livestock production. Proceedings of the 15th International Congress of the International Society for Animal Hygiene, Vienna, Austria, 3-7 July 2011, Tribun EU, 2: 973-975. Available at: https://www.cabdirect.org/cabdirect/abstract/20113296225

Al- Kour MS (2001). Microbiological states of meat and some meat products in northern Jordan. M.V.Sc. Thesis, Faculty of Veterinary Medicine, Jordan University of Science and Technology. Available at: https://www.semanticscholar.org/paper/Microbiological-status-of-meat-and-some-meat-in-Al.-Ekour/8c40eddb6ec483f773a193a0a83b00b9b5955b20

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Alahakoon U, Jayasena D, Ramachandra S, and Jo C (2015). Alternatives to nitrite in processed meat: Up to date. Trends in Food Science and Technology, 45(1): 37-49. DOI: https://www.doi.org/10.1016/j tifs.2015.05.008

Ali ME, Al Amin M, Hamid, SBA, Hossain MM, and Mustafa S (2015). Lab-on-a-chip-based PCR-RFLP assay for the confirmed detection of short-length feline DNA in food. Food Additives and Contaminants: Part A, 32(9): 1373-1383. DOI: https://www.doi.org/10.1080/19440049.2015.1075068

Al-Yazeed HA, Hassan AA, and Tawakkol W (2015). Contamination of meat and meat products with Aspergillus species and aflatoxin and their control. pp.1-18. DOI: https://www.doi.org/10.13140/RG.2.1.4922.7364

American Public Health Association (APHA) (1992). Standard methods for the microbiological examination of dairy products. 16th Ed., American Public Health Association, Washington, D.C., USA. Available at: https://agris.fao.org/agris-search/search.do?recordID=US19950104912

Balaban N, and Rasooly A (2000). Staphylococcal enterotoxins. International Journal of Food Microbiology, 61: 1-10. DOI: https://www.doi.org/10.1016/s0168-1605(00)00377-9

Bale JA, de Pinna EM, Threlfall EJ, and Ward LR (2007). Kauffmann-White scheme: *Salmonella* identification - serotypes and antigenic formulae. London: health protection agency. Available at: https://www.worldcat.org/title/kauffmann-white-scheme-2007-salmonella-identification-serotypes-and-antigen-formulae/oclc/228193783?referer=di&ht=edition

Biesalski HK (2005). Meat as acomponent of a healthy diet Are there any risks or benefis if meat is avoided in the diet?. Meat Science, 70: 509-524. DOI: https://www.doi.org/10.1016/j meatsci.2004.07.017

Datta S, Akter A, Shah IG, Fatema K, Islam TH, Bandyopadhyay A, Khan ZUM, and Biswas D (2012). Microbiological quality assessment of raw meat and meat products and antibiotic, susceptibility of isolated *Staphylococcus aureus*. Agriculture, Food and Analytical Bacteriology, 2(3): 187-194. Available at: https://eprints.whiterose.ac.uk/115212/

Davies RH, and Wray C (1997). Immunomagnetic separation for enhanced flagellar antigen phase inversion in Salmonella: Bacteriology Department,Central Veterinary Laboratory, Addlestone, Surrey, UK. Lett. Applied Microbiology, 24: 217-220. DOI: https://www.doi.org/10.1046/j.1472-765x.1997.00390.x

Edwards PR, and Ewing WH (1972). Identification of enterobacteriacae. Minneapolis, Burgess Publishing Company, Burgess Publishing Company. Atlanta United States of America 3rd edition, P. 709. Available at: https://www.worldcat.org/title/identification-of-enterobacteriaceae/oclc/857371

Elmossalami EIK (2003). Risk assessment of ready prepared meat products. Ph.D.Thesis, Meat Hygiene. Faculty of Veterinary Medicine, Cairo University. Available at: http://srv4.eulc.edu.eg/eulc_v5/libraries/start.aspx?ScopeID=1.4.7.&fn=ApplySearch&criteria1=1.&OrderKey=publishYear+desc&SearchText1=Risk+assessment+of+ready+prepared+meat+products&ItemType=24.2.5

Elsayed ME, Algammal AM, El-Diasty EM, Abouelmaatti RR, and Abbas SM (2018). Prevalence of *Aspergillus* spp and Aflatoxins in luncheon, minced meat and sausage. Global Animal Science Journal-GASJ, 6(2): 17-23. DOI: https://www.doi.org/10.5281/zenodo.1476984

El-Shazly E, El-Shinawy NM, and Tolba KS (2016). Molecular assay using PCR based technology to identify fraud and adulteration of some meat products. Benha Veterinary Medical Journal, 31(2): 33-39. DOI: https://www.doi.org/10.21608/bvmj.2016.31257

El-Shewy EA (2007). Identification of meat species in some ready to eat meat products sold in Egyptian markets. Zagazig Veterinary Journal, 35(2): 10-18. Available at: https://bu.edu.eg/staff/elhamalshiwy1-publications/10569

Erdem AK, Saglam D, Ozer D, and Ozcelik E (2014). Microbiological quality of minced meat samples marketed in Istanbul. Van Veterinary Journal, 25: 67-70. Available at: http://vfdergi.yyu.edu.tr/archive/2014/25-3/2014_25_(3)_67-70.pdf

Galal-Khallaf A (2021). Multiplex PCR and 12S rRNA gene sequencing for detection of meat adulteration: A case study in the Egyptian markets. Gene, 764: 145062. DOI: https://www.doi.org/10.1016/j.gene.2020.145062

Gokulakrishnan P, and Vergis J (2015). Molecular methods for microbiological quality control of meat and meat products: A review. Critical Reviews in Food Science and Nutrition, 55(10): 1315-1319. Available at: https://pubmed.ncbi.nlm.nih.gov/24915322/

Gönülalan Z, and Köse A (2003). Kayseri ilinde satışa sunulan sığır kıymalarının mikrobiyolojik kalitesi. FÜ Sağlık Bil Derg, 17: 49-53. Available at: https://avesis.kayseri.edu.tr/yayin/f1ef4b6b-fdb4-4e82-83b9-67025f91c23e/kayseri-ilinde-satisa-sunulan-sigir-kiymalarinin-mikrobiyolojik-kalitesi

Gourama H, and Bullerman LB (1995). Aspergillus flavus and *Aspergillus* parasiticus: Aflatoxigenic fungi of concern in foods and seeds: A review. Journal of Food Protection, 58(12): 1495-1404. DOI: https://www.doi.org/10.4315/0362-028x-58.12.1395

Haunshi S, Basumatary R, Girish PS, Doley S, Bardoloi RK, and Kumar A (2009). Identification of chicken, duck, pigeon and pig meat by species-specific markers of mitochondrial origin. Meat Science, 83(3): 454-459. DOI: https://www.doi.org/10.1016/j.meatsci.2009.06.026

Hussein MAM (2008). Mycological aspect of fresh and processed meat products with special respect to proteolytic and lipolytic mold. Ph.D. Thesis (Meat Hygiene) Faculty Veterinary Medicine, Zagazig University, Egypt. Available at: http://srv4.eulc.edu.eg/eulc_v5/Libraries/Thesis/BrowseThesisPages.aspx?fn=PublicDrawThesis&BibID=10284763

Ilhak OI, and Arslan A (2007). Identification of meat species by Polymerase Chain Reaction (PCR) technique. Turkish Journal of Veterinary Animal Science, 31(3): 159-163. Available at: https://www.semanticscholar.org/paper/Identification-of-Meat-Species-by-Polymerase-Chain-Ilhak-Arslan/dfcafd6d328700e2efe9932395438f6d00182777

Ismail SA, Shehata AA, and El-diasty EM (2013). Microbiological quality of some meat products in local markets with special reference to mycotoxins. Journal of Global Veterinaria, 10(5): 577-584. Available at: https://www.semanticscholar.org/paper/Microbiological-Quality-of-Some-Meat-Products-in-to-Ismail-Shehata/bdf2f2eb4ac6c41b9a85c2ac60fee9990cf5b2e7

Jaayid TA (2013). Rapid and sensitive identification of horse and donkey meat in Iraqi markets using SSR and PCR-RFLP based on mitochondrial DNA Cytochrome B gene. Journal of Agricultural Science and Technology, 3: 896-903. Available at: https://www.semanticscholar.org/paper/Rapid-and-Sensitive-Identification-of-Horse-and-in-Talib-Ahmed/d8e21db69dffaf28337475f27eb1fc22a950eb35

To cite this paper: Abuelnaga ASM, Abd El-Razik KhAE-H, Hassan Soliman MM, Sultan Ibrahim H, Abd-Elaziz MMM, Elgohary AH, Hedia RH, and Elgabry EA-E (2021). Microbial Contamination and Adulteration Detection of Meat Products in Egypt. *World Vet. J.*, 11 (4): 735-744. DOI: https://dx.doi.org/10.54203/scil.2021.wvj94

Kesmen Z, Sahin F and Yetim H (2007). PCR assay for the identification of animal species in cooked sausages. Meat Science, 77: 649-653. DOI: https://www.doi.org/10.1016/j.meatsci.2007.05.018

Kesmen Z, Yetim H, and Şahin F (2010). Identification of different meat species used in sucuk production by PCR assay. Gida, 35: 81-87. Available at: https://www.semanticscholar.org/paper/Identification-of-Different-Meat-Species-Used-In-By-Kesmen-Yetim/c9ad0cfd7f471955339ee9ddb1d9a7e38b98ff4c

Khairalla KMS, Hago BE, Hassan T, Majid AA, Dafalla EA, Karrar AE, and Aradaib IE (2005). Rapid detection of pork in processed food using PCR Amplification technology. Asian Network for scientific information. Pakistan Journal of Biological Sciences, 8(3): 501-504. Available at: https://scialert.net/abstract/?doi=pjbs.2005.501.504

Martín J, Garcıa T, Fajardo V, Rojas M, Hernandez PE, Gonzalez I, and Martın R (2007). Technical note: Detection of cat, dog, and rat or mouse tissues in food and animal feed using species-specific polymerase chain reaction. Journal of Animal Science, 85(10): 2734-2739. DOI: https://www.doi.org/10.2527/jas.2007-0048

Mehdizadeh M, Mousavi SM, Rabiei M, Moradian K, Eskandari S, Fesarani M, Abbasi Rastegar H, and Alebouyeh M (2014). Detection of chicken meat adulteration in raw hamburger using polymerase chain reaction. Journal of Food Quality and Hazards Control, 1: 36-40. Available at: https://www.magiran.com/paper/1294500/?lang=en

Meyer R, Chardonnens F, Hiibner P, and Liithy J (1996). Polymerase chain reaction (PCR) in the quality and safety assurance of food: Detection of soya in processed meat products. Zeitschrift für Lebensmittel-Untersuchung und Forschung, 203: 339-344. DOI: https://www.doi.org/10.1007/bf01231072

Moawad AA, Hotzel H, Awad O, Tomaso H, Neubauer H, Hafez HM, and El-Adawy H (2017). Occurrence of Salmonella enterica and Escherichia coli in raw chicken and beef meat in Northern Egypt and dissemination of their antibiotic resistance markers. Gut Pathogens, 9(1): 1-13. DOI: https://www.doi.org/10.1186/s13099-017-0206-9

Morshdy AM, El-Atabany AI, Hussein MA, and Naser MAS (2013). Detection of entertoxigenic staphylococcus aureus in some meat products. Assiut Veterinary Medical Journal, 59: 100-106. DOI: https://www.doi.org/10.21608/avmj.2013.171500

Mousa MM, Ahmed AA, and El-Shamy SY (2014). Microbiological criteria of some meat products. Alexandria Journal for Veterinary Sciences, 42(1): 83-89. DOI: https://www.doi.org/10.5455/ajvs.162116

Naas HT, Garbaj AM, Elarbed, ZM, Eshamah HL, and Abolghait SK (2009). Microbial status of fresh beef sausage sold in Tripoli. Suez Canal Veterinary Medical Journal, 14(2): 111-118. Available at: https://www.semanticscholar.org/paper/MICROBIAL-STATUS-OF-FRESH-BEEF-SAUSAGE-SOLD-IN-Naas-Garbaj/dd51e0ce8cc8c32489843620895a169f1ee68d59

Nørrung BJ, Andersen K, and Buncic S (2009). Main concerns of pathogenic microorganisms in meat safety of meat and processed meat. In Safety of meat and processed meat. Springer, New York, pp. 3-29. Available at: https://link.springer.com/chapter/10.1007/978-0-387-89026-5_1

Omran GA, Tolba AO, El-Sharkawy EE, Abdel-Aziz DM, and Ahmed HY (2019). Species DNA-based identification for detection of processed meat adulteration: is there a role of human short tandem repeats (STRs)? Egyptian Journal of Forensic Sciences, 9: 15. DOI: https://www.doi.org/10.1186/s41935-019-0121-y

Partis L, Croan D, Guo Z, Clark R, Coldham T, and Murby J (2000). Evaluation of a DNA fingerprinting method for determining the species origin of meats. Meat Science, 54: 369-376. DOI: https://www.doi.org/10.1016/S0309-1740(99)00112-6

Ragab WS, Hassan EA, Al-Geddawy MA, and Albie AA (2016). Bacteriological quality of some meat products in the Egyptian retail markets. Assiut Journal of Agricultural Sciences, 47: 422-429. DOI: https://www.doi.org/10.21608/ajas.2016.2755

Salem AM, Amin RA, and Afifi GS (2010). Studies on antimicrobial and antioxidant efficiency of some essential oils in minced beef. Journal of American Science, 6: 691-700. Available at: https://www.semanticscholar.org/paper/Studies-on-Antimicrobial-and-Antioxidant-Efficiency-Amany-Salem/d1efb46ddc06a6b252c4c48a30d59d4ce1e7dd4d

Samson RA, Houbraken J, Thrane U, Frisvad JC, and Andersen B (2010). Food and indoor fungi. CBS Laboratory Manual Series, pp. 19-21. Available at: https://www.worldcat.org/title/food-and-indoor-fungi/oclc/703787403

Shaltout FA, Salem AM, Khaterb DF, and Lela RA (2016). Studies on bacteriological Profile of some meat products. Benha Veterinary Medical Journal, 31(1): 43-49. Available at: https://bvmj.journals.ekb.eg/article_31216.html

Soares S, Amaral JS, Beatriz PP, Oliveira M, andMafra I (2013). A SYBR Green real-time PCR assay to detect and quantify pork meat in processed poultry meat products. Meat Science, 94: 115-120. DOI: https://www.doi.org/10.1016/j.meatsci.2012.12.012

Soliman MMH, Ata NS, El-Shafei HM, and Kandil MMA (2019). Prevalence of toxigenic *Aspergillus flavus* in meat and meat products. Bioscience Research, 16(1): 822-829. Available at: https://www.isisn.org/BR_16_1_2019.htm

Stagnitta PV, Micalizzi B, and de Guzmán AMS (2006). Prevalence of some bacteria yeasts and molds in meat foods in San Luis, Argentina. Central European Journal of Public Health, 14(3): 141-144. DOI: https://www.doi.org/10.21101/cejph.a3378

Tafvizi F, and Hashemzadegan M (2016). Specific identification of chicken and soybean fraud in premium burgers using multiplex-PCR method. Journal of Food Science and Technology, 53(1): 816-823. DOI: https://www.doi.org/10.1007/s13197-015-1771-x

Xu W, Bai W, Luo Y, Yuan Y, Zhang W, Guo X, and Huang K (2008). A novel common single primer multiplex polymerase chain reaction (CSP-M-PCR) method for the identification of animal species in minced meat. Journal of the Science of Food and Agriculture, 88: 2631-2637. DOI: https://www.doi.org/10.1002/jsfa.3382

Yacoub HA, and Sadek MA (2017). Identification of fraud (with pig stuffs) in chicken-processed meat through information of mitochondrial cytochrome b. Mitochondrial DNA A DNA Mapping Sequence Analysis, 28(6): 855-859. Available at: https://pubmed.ncbi.nlm.nih.gov/27871208/

Yosef TA, Al-Julaifi MZ, and Al-Rizqi AM (2014). Food forensics: Using DNA-based technology for the detection of animal species in meat products. Nature and Science, 12: 82-90. Available at: https://www.semanticscholar.org/paper/Food-Forensics%3A-Using-DNA-Based-Technology-for-the-Yosef-T.a/a85912b65e119aa03ab2e0bdf4779b5435b891f0

Zahran D, and Hagag S (2015). Use of molecular biology techniques in the detection of fraud meat in the Egyptian market. African Journal of. Biotechnology, 14(5): 360-364. DOI: https://www.doi.org/10.5897/ajb2014.14297

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