Dept. of Food Hygiene,
Fac. of Vet. Med., Assiut Uni., Egypt.

MICROBIOLOGICAL QUALITY OF COMMERCIAL MAYONNAISE SOLD IN ASSIUT CITY
(With 2 Tables)

By

MOHAMMED SAYED and AMAL ALI ABDEL-HALEEM*
* Assiut Animal Research Center.
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الجودة الميكروبيولوجيه للمايونيز التجاري المباع بمدينة أسيوط

محمد سيد ، أمال علي عبد الحليم

يستخدم المايونيز كثيراً هذه الأيام بمفرده أو يضاف إلى الأطعمة كأحد المشـهيات بجانـب الوجبات الرئيسية وذلك على نطاق واسع. لذلك أجريت هذه الدراسة وفيها تم جمـع عـدد ٣٠ عينة عشوائية من المايونيز التجاري المعروض للبيع والمتداول بالأسواق من العديد من المحال التجارية في مدينة أسيوط لفحصها ميكروبيولوجياً وذلك لتحديد مدى حالتها الصـحية وسلامتها للمستهلك. وقد تم تقدير كـلاً مـن aerobic plate count و psychrotrophs و thermoduric و enterococci و coliforms و fecal coliforms و E.coli و B.cereus و S.aureus و anaerobes و molds & yeasts. وقد أظهرت النتائج أن متوسط العـدد الكلـي لكـل مـن aerobic plate count و psychrotrophs و thermoduric و enterococci كالتالي : $3x10^4$ ، $1.7x10^3$ ، $2.7x10^4$ ، $2.9x10^3$ لكل جرام من عينات المايونيز، على التوالي. ولقد تم عزل B.cereus من 20% بمتوسط أعـداد $1x10^3$ لكـل جرام من عينات المايونيز. وقد لوثت 26.67% yeasts & molds مـن العينـات وذلـك بمتوسط أعداد $2.2x10^2$ لكل جرام. وبالبحث عن coliforms تبين من الفحـص أن كـل عينات المايونيز قد وجدت خالية من هذا الميكروب (أقل من 3 للجرام) وبالتالي لم يتم عزل fecal coliforms ومن ثم E.coli. كذلك S.aureus و anaerobes لم يتم عزلهما مـن كل العينات. وقد ظهر من هذه النتائج أن عينات المايونيز التجاري المباع بمدينـة أسـيوط تعتبر جيدة من الحالة الميكروبيولوجيه والجودة الصحية. ورغم إن الحمل الميكروبي تحـت معدل الخطر إلا أن خطورة هذه الميكروبات مازالت موجودة ولذلك فقد تم إتاحة الفرصـة لبعض الميكروبات الممرضة لكي تنمو وتتكاثر وذلك من خلال الجـزء الثـاني مـن هـذه الدراسة حيث تم إجراء تجربة معملية بهدف معرفة التأثير المباشر للمايونيز على 5 عترات لميكروبات ضارة وهـي: S.typhimurium, E.coli O157:H7, L.monocytogenes, S.aureus and B.cereus، حيث تم حقن كل عينة مايونيز بميكروب كل على حـده ثـم التحضين عند درجة حرارة الغرفة حيث أنها الدرجة التي يتم توزيــع وعـرض وتخـزين المايونيز فيها. وتم أخذ عينات بعد الحقن بمعدل عدد ساعات: ٦، ٢٤، ٤٨، ٧٢ ساعة. وقد أسفرت النتائج عن التأثير الفعال والمميت للمايونيز على الميكروبات المحقونة رغم بقاء كلا

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من *B.cereus* and *L.monocytogenes* بصورة أطول نسبياً عن باقي العزلات. هذا وقد تمت مناقشة الإجراءات الصحية والشروط الواجب إتباعها لتحسين جودة المايونيز وكذلك تم مناقشة مدى خطورة هذه الميكروبات على صحة وسلامة المستهلك.

SUMMARY

A total of 30 random samples of commercial mayonnaise were collected from different retailers in Assiut city. To assess their quality, the samples were examined microbiologically for the incidence and counts of aerobic plate count (APC), psychrotrophs, thermoduric, enterococci, coliforms, fecal coliforms, *Escherichia coli*, *Bacillus cereus*, *Staphylococcus aureus*, anaerobes and yeasts & molds. The obtained results verify that the total bacterial, psychrotrophs, thermoduric and enterococci counts averaged $3x10^4$, $1.7x10^3$, $2.7x10^4$ and $2.9x10^3$/g of the examined mayonnaise samples, respectively. *B. cereus* could be isolated from 20%, in numbers averaged $1x10^3$/g, of the examined mayonnaise samples. Yeasts & molds contaminated 26.67% of the examined mayonnaise samples and existed in numbers averaged $2.2x10^2$/g of the samples. All the examined mayonnaise samples failed to yield coliforms (less than 3/g), and therefore fecal coliforms and *E. coli* could not be recovered from all of the examined samples. Also, *S. aureus* and anaerobes could not be detected in any of mayonnaise samples examined. The results prove that the examined commercial mayonnaise samples sold in Assiut city are of quite good quality and considered as microbiologically safe products. Although, the microbial loads are below the hazard point, the health hazard of such microorganisms still exists if they are allowed to grow and multiply, and that what was studied through the second part of the present study, in which the survival and viability of *Salmonella typhimurium*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Staphylococcus aureus* and *Bacillus cereus* in commercial mayonnaise kept at room temperature were studied. Each mayonnaise sample was inoculated separately with one of the mentioned pathogenic microorganisms and then incubated at room temperature (about 25°C) as commercial mayonnaise is usually distributed, shelved and stored at this temperature. After that, the inoculated mayonnaise was sampled after 6, 24, 48 and 72 hours. The results revealed the lethal effect of mayonnaise on the inoculated microorganisms although the survival and viability of *L. monocytogenes* and *B. cereus* was relatively longer than others. Suggestive hygienic measures for improving the quality of mayonnaise and also to safeguard the consumer were discussed.

INTRODUCTION

Mayonnaise is a remarkable stable food product because of its resistance to most microbial spoilage and its unfavorable media for growth and survival of most bacteria especially pathogens. Consequently mayonnaise is of little public health concern as its overall microbiological content is low with a very low incidence of spoilage.

The microbiological content of mayonnaise is dictated primarily by the high acetic acid concentration found in their aqueous phase. The major preservative effect is from the acetic acid content with a minor influence from salt or sugar concentration (Smittle, 1977). Erickson and Jenkins (1991) reported that commercial mayonnaise represents negligible consumer's safety risks. However, mayonnaise has been found to be associated with outbreaks of food poisoning due to salmonella and staphylococci (Radford and Board, 1993).

The nutrient content of mayonnaise is suitable for supporting growth of many spoilage microorganisms such as yeasts, few bacteria and molds (Jay, 1978), therefore, bacilli and yeasts are the organisms commonly found (Smittle, 1977). The growth of microorganisms takes place in aqueous phase of mayonnaise and causes alterations of sensory quality and changes with potentially toxic effects (Traveria, 1992).

This study was designed as an attempt to throw spotlight on the microbial aspects of commercial mayonnaise sold in Assiut city, in addition to, studying the survival of 5 strains of pathogenic microorganisms (*S. typhimurium, E. coli* O157:H7, *L. monocytogenes, S. aureus* and *B. cereus*) that were inoculated separately in commercial mayonnaise samples and kept at room temperature.

MATERIALS and METHODS

Collection of samples:

A total of 30 random samples of commercial mayonnaise were collected from different retailers in Assiut city. All samples were dispatched directly to the laboratory under strict hygienic measures with a minimum of delay.

Preparation of samples:

The samples were opened aseptically and 10 g of each sample were aseptically weighed and added to 90 ml of 0.1% sterile peptone water and homogenized for 2 minutes to obtain a dilution of 10^{-1} (APHA, 1992), then decimal dilutions were made and followed by microbiological examination.

Microbiological examination:

1- APC, (APHA, 1992).
2- Psychrotrophic count, (APHA, 1985).
3- Thermoduric count, (APHA, 1985).
4- Enterococci count, (Deibel and Hartman, 1982).
5- Coliforms count (MPN/g), (AOAC, 1980).
6- Enumeration of fecal coliforms (MPN/g), (AOAC, 1980).
7- Enumeration of *E. coli* (MPN/g), (AOAC, 1980).
8- Enumeration and isolation of *B. cereus*, (Kim and Goepfert, 1971) followed by:
    a) Nitrate reduction test, (Speck, 1976).
    b) Gelatin liquefaction test, (Cowan and Steel, 1974).
    c) Voges-Proskauer test, (Speck, 1976).
9- Isolation of *S. aureus*, (Finegold and Martin, 1982) followed by:
    a) Gram staining, (Speck, 1976).
    b) Anaerobic mannitol fermentation, (Baired-Parker, 1962).
    c) Coagulase test, (Cruickshank *et al.*, 1969).
10- Detection of anaerobes by stormy fermentation test, (Cruickshank *et al.*, 1969).
11- Yeasts & molds count, (Harrigan and MeCance, 1976).

Strains used and inoculation technique:

Five pathogenic strains were used individually as an inoculum involving *S. typhimurium* NC000074 that was obtained from National Collection of Type Cultures, London; *E. coli* O157:H7, *L. monocytogenes*, *S. aureus* and *B. cereus* that were obtained from Department of Food Hygiene, Faculty of Veterinary Medicine, Assiut University, Egypt. Each strain was grown individually in 100 ml sterile nutrient broth, at 37°C for 24 hours. Serial dilutions were done for counting cfu/ml. One ml of the inoculum of known cfu/ml was added aseptically to mayonnaise sample under a static hood to obtain a concentration of 7×10^3, 1×10^1, 3×10^4, 1×10^4 and 4×10^5 cfu/g of mayonnaise for each microorganism, respectively. The inoculated sample was thoroughly mixed for 2-3 minutes with sterile spoon for

uniform distribution and then corked effectively with metal-screw caps and incubated at room temperature (about 25°C) and sampled periodically after 6, 24, 48 and 72 hours.

pH measurement:

pH was measured using a digital laboratory pH meter (model 701A / digital ionalyzer, Orion).

RESULTS

Table 1: Microbial counts of the examined commercial mayonnaise samples.

Microbiological examination	Positive samples		Counts/g		
	No./30	%	Minimum	Maximum	Average
APC	22	73.33	$<10^{2*}$	3.2×10^5	3×10^4
Psychrotrophic count	6	20	$<10^{2*}$	3×10^4	1.7×10^3
Thermoduric count	26	86.67	$<10^{2*}$	2.3×10^5	2.7×10^4
Enterococci count	2	6.67	$<10^{2*}$	8×10^4	2.9×10^3
B. cereus count	6	20	$<10^{2*}$	1×10^4	1×10^3
Yeasts & molds count	8	26.67	$<10^{1*}$	3.5×10^3	2.2×10^2

*No colonies could be counted on the plates.

Table 2: Behavior of some pathogenic microorganisms in commercial mayonnaise samples (cfu/ml or g).

Time (hour)	S.typhimurium	E.coli O157:H7	L.monocytogenes	S.aureus	B.cereus
Inoculum	7×10^3	1×10^1	3×10^4	1×10^4	4×10^5
6 hours	-	-	3×10^3	-	6×10^2
24 hours	-	-	1×10^3	-	5×10^2
48 hours	-	-	-	-	-

DISCUSSION

The summarized results presented in Table 1 pinpoint that 73.33% of the examined commercial mayonnaise samples had countable numbers of total bacteria, ranged from $<10^2$ to 3.2×10^5 with an average of 3×10^4/g. Comparatively, lower counts were obtained by Fabian and Wethington (1950), who mentioned that the microbial count of mayonnaise was very low (<10/g). It is worth to mention that higher total bacterial counts in the examined mayonnaise samples did not prove the presence of pathogens but they reflect the unhygienic

status of such product during processing, post manufacturing or during handling. It may also occur through using of raw and cracked eggs (Palmu, 1992 and Radford and Board, 1993).

The results obtained from the examined mayonnaise samples in Table 1 revealed that 20% had numbers of psychrotrophs averaged 1.7×10^3/g. It is precisely evident from these results that the high incidence and counts of psychrotrophic bacteria could be attributed to ineffective processing and sanitizing methods, as well as use of unpasteurized eggs. Most of psychrotrophic bacteria are destroyed by a mild heat treatment, however, their presence implies post processing contamination and existence of heat resistant types such as Bacillus and Clostridium (Bhadsavle *et al.*, 1972). Generally, in foods that are kept refrigerated till reach consumers or served, large numbers of psychrotrophic bacteria may indicate a history of unsanitary handling. Furthermore, some species of psychrotrophic bacteria are heat resistant or spore forming which cause problems in heat-treated products, as they produce heat resistant proteolytic and lipolytic enzymes that may cause spoilage of refrigerated products (Stevenson and Rowe, 1994 and Celestino *et al.*, 1996).

From the aforementioned results in Table 1, it was noticed that high percentage of mayonnaise samples (86.67%) contained thermodurics with an average of 2.7×10^4/g. Also, enterococci as recorded in Table 1 existed in 6.67% of the examined mayonnaise samples in numbers varied from $<10^2$ as a minimum to 8×10^4 as a maximum, with an average count of 2.9×10^3/g. No acceptable level of these bacteria can be stated because enterococci counts vary with the holding condition, time of storage and other factors. Nevertheless, the public health significance cannot be denied, especially when the organism is allowed to multiply and exist in tremendous numbers in the product, as they have been implicated in several food poisoning outbreaks (ICMSF, 1978).

It is obvious from the achieved results (Table 1) that 20% of the examined mayonnaise samples were contaminated by *B. cereus* in numbers ranged from less than 10^2 as a minimum to 1×10^4 as a maximum with an average count of 1×10^3/g. Although, *B. cereus* existed in low percentage (20%) with non-significant numbers, its public health hazard should not be neglected. It has been well documented that high numbers of *B. cereus* is needed to elicit symptoms of food poisoning. Therefore, the few numbers of *B. cereus* contaminating the samples should not be overlooked, as they can resist

heat processing (thermoduric) and can grow and multiply during refrigeration storage to reach numbers able to produce sufficient toxins to induce symptoms of food poisoning or even induce spoilage of the product (Richter *et al.*, 1992 and Meer *et al.*, 1993).

According to the results obtained, 26.67% of the examined mayonnaise samples were contaminated by yeasts and molds in numbers averaged $2.2 \times 10^2/g$ (Table 1). Higher incidence was obtained by Bahout *et al.* (1996), who found 100% of samples contained yeasts & molds. From the viewpoint of public health, certain strains of yeasts and molds when grow and multiply could be implicated in food poisoning outbreaks (Mossel, 1982).

None of the examined mayonnaise samples had coliforms (less than 3/g). These data prove that the examined mayonnaise samples had insignificant numbers of coliforms and all of the examined samples failed to recover fecal coliforms. Fortunately, no *E. coli* could be detected. However, coliforms and fecal coliforms still continue to be considered as indicator organisms of choice in examining foods, their absence indicate the good microbiological quality of the product. In recent years much attention has been paid towards *E. coli*, because of its importance as an organism of true fecal origin with possible existence of associated enteric pathogens.

As staphylococci count declines in high acid foods (Minor and Marth, 1972), *S. aureus* could not be detected in all of the examined mayonnaise samples. Also, anaerobes could not be detected at all. The obtained results are in accordance with Doyle *et al.* (1982) viewing mayonnaise of quite good microbial quality with levels of contamination beyond the hazard point.

It is known that the commercially prepared dressings such as mayonnaise have never been directly identified as a cause of any food borne illness. This performance is largely due to the intrinsic bactericidal nature of these products. Organic acids and acid ingredients contribute a desirable flavor for these products and are toxic to food borne pathogens (Brudzinski and Harrison, 1998). Acetic acid is the predominate acid which is added as various types of vinegars (Smittle, 2000).

The use of unpasteurized eggs in commercial mayonnaise was discontinued in the early 1970's, with most manufactures using exclusively USDA-certified pasteurized eggs. However, on rare occasions, sporadic low-levels contamination with Salmonella, Listeria and *E. coli* may occur in pasteurized eggs. Hence, the ability of the

acidity in mayonnaise to destroy food borne pathogens is of important consideration. However, 2 recent outbreaks in the Pacific Northwest epidemiologically implicated mayonnaise as a vehicle of _E. coli_ O157:H7 transmission.

Therefore, the purpose of the experimental work in this study was to determine the fate of some pathogenic microorganisms in commercial mayonnaise samples to evaluate the antimicrobial properties of such product as it is considered one of the microbiological safe food products.

The summarized results in Table 2 revealed that _S. typhimurium_ could not recover after 6 hours of its inoculation in mayonnaise and that could be attributed to its high acid content of acetic acid, which has greater antimicrobial effects than most other acids. Several studies have demonstrated that types of the acidulants would have different effects on microorganisms with acetic acid giving the greatest killing effect (Faber _et al._, 1989 and Sorrels _et al._, 1989). An acetic acid level of 0.7% or more in the aqueous phase which is commonly used in commercial mayonnaise is likely sufficient to kill Salmonella (Jeanne-Marie _et al._, 1997). Salmonella was observed to die off in homemade mayonnaise acidified with acetic acid (vinegar) more rapid than with citric acid (lemon juice) at the same pH (Perales and Garcia, 1990). Commercial pasteurized egg white is important in the manufacturing of cholesterol-free mayonnaise due to the presence of a synergistic effect of acetic acid and lysozyme or other antimicrobial substances in egg white on inactivating Salmonella in mayonnaise. Because microorganisms need water to grow and the oil is anhydrous, the water phase milieu or the water-oil interface is the portion of these products that is of primary concern. However, Radford _et al._ (1991) found that mayonnaise prepared from oil high in phenolic compounds, such as olive oil, can accelerate the death of Salmonella, the acid effects on growth and survival are primarily concentrated in the water phase components.

Concerning _E. coli_ O157:H7, no viability was noticed (Table 2) as sudden death was occurred after 6 hours of inoculation and that could be attributed to the low inoculum used (1 x 10^1 cfu/ml). However, Hathcox _et al._ (1995) commented as regardless of the inoculum level, death of _E. coli_ O157:H7 is most rapid at room temperature (20°C to 30°C) at which mayonnaise is stored, distributed and offered for sale in the marketplace. Weagant _et al._ (1994), Zhao and Doyle (1994), Raghubeer _et al._ (1995) and Hathcox _et al._ (1995)

demonstrated that *E. coli* O157:H7 could not survive in real mayonnaise or reduced-calorie mayonnaise dressing commercially prepared with good manufacturing practices.

Although *L. monocytogenes* had not been associated with mayonnaise, considering the wide spread distribution of this organism and the possibility of Listeria contamination of eggs, it would be beneficial to have an understanding of inactivation kinetics of *L. monocytogenes* in mayonnaise. This is particularly important considering the relatively high heat tolerance of *L. monocytogenes* in liquid whole egg as reported by Foegeding and Leasor (1990) who revealed that the minimal heat processing of 60°C for 3.5 minutes for pasteurization of liquid whole eggs would kill only 2 to 3 log_{10} *L. monocytogenes*/ml, thus the heavily contaminated whole eggs may be unsafe even after pasteurization for this pathogen. Therefore, the survival behavior of *L. monocytogenes* in the present study was required and recommended.

As recorded in Table 2 that *L. monocytogenes* could not able to persist viable after 24 hours after inoculation and that could be explained by the lethal effect of acetic acid accompanied by higher incubation temperature as *L. monocytogenes* has psychrotrophic nature (Glass and Doyle, 1991). Also, Erickson and Jenkins (1992) speculated that the anti-listerial activity was due to the egg white lysozome. Our findings was established before by FDA, as $>10^4$/g *L. monocytogenes* were inactivated within 72 hours holding period and this level of kill provides sufficient margin of safety considering that low levels of Listeriae (<10 cfu/g) normally are present when *L. monocytogenes* is detected in ingredients. As an additional margin of safety, under normal shipping and distribution practices, commercial mayonnaise must be 2 to 4 weeks old before it reaches the store shelves. Even excessive high levels ($>10^7$ cfu/g) of *L. monocytogenes* contamination, which is extremely unlikely situation, would be killed under these conditions.

Regarding *S. aureus*, it could not be detected after 6 hours (Table 2). Dolye *et al*. (1982) reported that commercial mayonnaise prevents growth of *S. aureus*. However, *S. aureus* has a potential hazard in mayonnaise and related products as the water activity of the product is not sufficiently low to preclude the growth of *S. aureus*. The organism is killed in mayonnaise with a pH <4.1 (Smittle, 1977). Therefore, Radford and Board (1993) concluded that in the preparation of homemade mayonnaise, vinegar should be used as the acidulant,

with pH less than or equal 4.1 and initial incubation at room temperature for 24 hours before refrigeration.

With focusing on the survival and behavior of *B. cereus*, it persisted alive till 24 hours and reached a count of 5 x 10^2 cfu/g (Table 2).

It is apparent from the obtained results that none of the pathogenic microorganisms inoculated into mayonnaise could be detected after 48 hours and that could be attributed to the antimicrobial properties of mayonnaise, in which, the acidity is the most important intrinsic characteristic in controlling the growth and survival of pathogenic bacteria. Secondly, salt and sugar play minor roles, but they have an interactive effect with acetic acid in vinegar on inhibiting the growth of food borne pathogens (Entani *et al.*, 1998). Therefore, it could be concluded from the aforementioned results (Table 2) that 48 to 72 hours holding at room temperature was sufficient to kill the pathogenic microorganisms inoculated into commercial mayonnaise samples having a pH of 4.95 to ensure safeness of the products. This conclusion was in agree with the requirement of federal regulations that commercially manufactured dressings such as mayonnaise made with unpasteurized eggs must have pH of less than or equal 4.1, an acetic acid level of the aqueous phase greater than or equal to 1.4%, and holding period of 72 hours before the product is shipped. These conditions were established to assure destruction of Salmonella, Listeria (Kathleen and Michael, 1991) and enterohaemorrhagic *E. coli* (Errol *et al.*, 1994). Unfortunately, these inhibitory effects of mayonnaise could be compromised if this product is contaminated in a food service establishment and then diluted in preparation of other foods. Therefore, it is important that food service establishment and households be aware that when preparing food with mayonnaise, the acidity and pH derived from the mayonnaise can not ensure the inhibition of growth of pathogenic bacteria by cross-contamination of such prepared food.

Finally, good manufacturing practices and the implementation of Hazard Analysis Critical Control Point (HACCP) program in food manufacturing and food preparation should be done to improve quality and control pathogenic microorganisms of commercial mayonnaise.

REFERENCES

AOAC (Association Official Analytical Chemists) (1980): Official methods of analysis. 15th Ed. Benjamin Franklin Station, Washington.

APHA (American Public health Association) (1985): Standard methods for examination of the dairy Products. 15th Ed. Washington DC, USA.

APHA (American Public health Association) (1992): Standard method for examination of dairy Products. 13th Ed. Washington DC, USA.

Bahout, A.A.; Nassar, A. and Saleh, E.A. (1996): Microbial aspects of locally manufactured mayonnaise. Assiut Vet. Med. J. 34:30.

Baired-Parker, A.C. (1962): An improved diagnostic and selective medium for isolating coagulase-positive staphylococci. J. Appl. Bact. 25:12.

Bhadsavle, C.H.; Shehata, T.E. and Collins, E.B. (1972): Isolation and identification of psychrophilic species of clostridium from milk. Appl. Microbiol. 24: 699.

Brudzinski, L. and Harrison, M.A. (1998): Influence of incubation conditions on survival and acetic tolerance response of *E. coli* O157:H7 and non-O157:H7 isolates exposed to acetic acid. J. Food Prot. 61:542.

Celestino, E.L.; Lyer, M. and Roginski, H. (1996): The effect of refrigerated storage on the quality of raw milk. Australian J. Dairy Technol. 51:59.

Cowan, S.T. and Steel, K.J. (1974): Manual for identification of medical bacteria. 2nd Ed. Cambridge, Cambridge University Press.

Cruickshank, R.; Duguid, J.P. and Swain, R.H. (1969): Medical microbiology. 11th Ed. E.S. Livingston Limited Edinburgh, London.

Deibel, R.H. and Hartman, P.A. (1982): The enterococci. In: Compendium of methods for the microbiological examination of foods. Speck, M.L. (ed.), 2nd Ed. APHA.

Doyle, M.P.; Bains, N.J.; Schoeni, J.L. and Foster, E.M. (1982): Fate of *Salmonella typhimurium* and *Staphylococcus aureus* in meat salads prepared with mayonnaise. J. Food Prot. 45: 152.

Entani, E.; Asai, M.; Tsujihata, S.; Tsukamoto, Y. and Ohta, M. (1998): Antibacterial action of vinegar against foodborne pathogenic bacteria including *E. coli* O157:H7. J. Food Prot. 61: 953.

Erickson, J.P. and Jenkins, P. (1991): Comparative Salmonella sp. and *Listeria monocytogenes* inactivation rates in four commercial mayonnaise products. J. Food Prot. 54: 913.

Erickson, J.P. and Jenkins, P. (1992): Behavior of psychrotrophic pathogens *Listeria monocytogenes, Yersinia enterocolitica* and *Aeromonas hydrophila* in commercially pasteurized eggs held at 2, 6, 7 and 12.8°C. J. Food Prot. 55: 8.

Errol, V.R.; Jims, K.; Mechael, L.C. and Richard, S.M. (1994): Fate of *E. coli* O157:H7 and other coliforms in commercial mayonnaise and refrigerated salad dressing. J. Food Prot. 58: 13.

Faber, J.M.; Sanders, G.W.; Dunfield, S. and Prescott, R. (1989): The effects of various acidulants on the growth of *Listeria monocytogenes.* Lett. Appl. Microbiol. 9: 181.

Fabian, F.W. and Wethington, M.C. (1950): Bacterial and chemical analyses of mayonnaise, salad dressings and related products. Food Res. 15: 138.

Finegold, S.M. and Martin, W.J. (1982): Bailley and Scott Diagnostic Microbiology. 6th Ed. C.V. Mosby. Co. St. Louis, Toronto, London.

Foegeding, P.M. and Leasor, C.B. (1990): Heat resistance and growth of *Listeria monocytogenes* in liquid whole egg. J. Food Prot. 53:9.

Glass, K.A. and Doyle, M.P. (1991): Fate of Salmonella and *Listeria monocytogenes* in commercial, reduced-calorie mayonnaise. J. Food Prot. 54: 691.

Harrigan, W.F. and MeCance, M.E. (1976): Laboratory methods in food & dairy microbiology. Academic press, London, New York, San Francisco.

Hathcox, A.K.; Beuchat, L.R. and Doyle, M.P. (1995): Death of enterohemorrhagic *Escherichia coli* O157:H7 in real mayonnaise and reduced-calorie mayonnaise dressing as influenced by initial population and storage temperature. Appl. Environ. Micrbiol. 61: 4172.

ICMSF (International Commission Microbiological Specification Foods) (1978): Microorganisms in foods, their significance and methods of enumeration. Toronto Univ. Toronto Press. Toronto and Buffalo, Canada.

Jay, J.M. (1978): Modern Food Microbiology. 2nd Ed. D. Van Nostrand Company, New York.

Jeanne-Marie, M.; Virginie, M. and Isabelle, J. (1997): Effects of temperature, pH, glucose and citric acid on the inactivation of *Salmonella typhimurium* in reduced calorie mayonnaise. J. Food Prot. 60: 1497.

Kathleen, A.G. and Michael, P.D. (1991): Fate of Salmonella and *Listeria monocytogenes* in commercial reduced-calorie mayonnaise. J. Food Prot. 54: 691.

Kim, H.V. and Goepfert, J.M. (1971): Enumeration and identification of *Bacillus cereus* in foods. 1. 24. hour presumptive test medium. Appl. Microbiol. 22: 581.

Meer, R.R.; Wodburn, M.J. and Bodyfelt, F.W. (1993): Identification and characterization of heat-resistant psychrotrophic bacteria in Oregon Grade A raw milk. Dairy Food Environ. Sanitation. 13: 631.

Minor, T.E. and Marth, E.H. (1972): Loss of viability by *Staphylococcus aureus* in acidified media, Inactivation by several acid mixture of acids and salts of acids. J. Milk Food Technol. 35: 190.

Mossel, D.A.A. (1982): Microbiology of food. 3rd Ed. Utrecht Univ. The Netherlands ISBN.

Palmu, L. (1992): An outbreak of foodborne disease caused by *Salmonella enteritidis* in Turku, Finland during summer of 1991: a case report. Suomen Eläinlääkrä-rilehti. 98: 202.

Perales, I. and Garcia, M.I. (1990): The influence of pH and temperature on the behavior of *Salmonella enteritidis* phage type 4 in home made mayonnaise. Lett. Appl. Microbiol. 10:19.

Radford, S.A. and Board, R.G. (1993): Fate of pathogens in home made mayonnaise and related products. Food Microbiol. 10: 269.

Radford, S.A.; Tassou, C.C.; Nychasand, G.J.E. and Broad, R.G. (1991): The influence of different oils on the death rate of *Salmonella enteritidis* in home made mayonnaise. Lett. Appl. Micrbiol. 12: 123.

Raghubeer, E.V.; Ke, J.S.; Campbell, M.L. and Meyer, R.S. (1995): Fate of *Escherichia coli* O157:H7 and other coliforms in commercial mayonnaise and refrigerated salad dressing. J. Food Prot. 58:13.

Richter, R.L.; Ledford, R.A. and Murphy, S.C. (1992): Milk and milk products. Compendium of methods for the microbiological examination of foods. Vanderzant, C. and Splittstoesser, D.F. 3rd Ed. P. 841. APHA. Washington DC, USA.

Smittle, R.B. (1977): Microbiology of mayonnaise and salad dressing: a review. J. Food Prot. 40: 415.

Smittle, R.B. (2000): Microbiological safety of mayonnaise, salad dressing and sauces produced in the United States: a review. J. Food Prot. 63:1144.

Sorrels, K.M.; Enigland, D.C. and Hatfield, J.R. (1989): Effect of pH, acidulant, time and temperature on the growth and survival of *Listeria monocytogenes.* J. Food Prot. 52: 571.

Speck, M.L. (1976): Compendium of methods for the microbiological examination of foods. 2nd Ed. APHA, Washington DC.

Stevenson, G. and Rowe, M. (1994): Spoilage of dairy products by psychrotrophic bacteria. Milk Industry London. 6: 11. Technical and Processing Suppl. 15-16.

Traveria, T. (1992): Microbiological safety and stability of oil in water emulsions used in foods, mayonnaise and sauces. Alimentaction Equipos Y Technologia. 11: 66.

Weagant, S.D.; Bryant, J.L. and Bark, D.H. (1994): Survival of *Escherichia coli* O157:H7 in mayonnaise and mayonnaise-based sauces at room and refrigerated temperature. J. Food Prot. 57: 629.

Zhao, T. and Doyle, M.P. (1994): Fate of enterohemorrhagic *Escherichia coli* O157:H7 in commercial mayonnaise. J. Food Prot. 57: 780.