International Food Research Journal 20(5): 2335-2341 (2013)
Journal homepage: *http://www.ifrj.upm.edu.my*

Continuous improvement of a system quality management: accelerating thawing process of poultry meat by using a microwave oven

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Article history

Received: 28 June 2012
Received in revised form: 10 June 2013
Accepted: 14 June 2013

Keywords

Thawing process
Poultry meat
Chicken
Microwave oven
Quality management

Abstract

The present work aims to validate the application of accelerating thawing process (microwave oven 20 kW/60 seconds) for poultry meat chicken. Hence, several criteria, such as microbiological, organoleptic, nutritional, thawing time and cost, were evaluated by accelerated and slow processes (48 h during 4°C, reference method). After 5 weeks, and according to the microbiological criteria the results of counting organisms (Total mesophilic flora, (TMF); Fecal coliforms, Sulphite reducing anaerobic (SRA); *Staphylococcus aureus* and *Salmonella* spp.) under the two processes are satisfying and meet the standards. However, we noted that the obtained TMF's averages by the accelerate process are lower than those obtained by the slow process from the upper boxes ($1.02\ 10^2 < 5.82\ 10^2$ CFU/g) or from the boxes of the bottom ($0.84\ 10^2 < 3.24\ 10^2$ CFU/g). Yet, by the rapid process organoleptic and nutritional qualities of meat are better preserved. Moreover, the rapid process reduces the thawing time (saving time 33h).The organoleptic study indicates that the quality of the poultry meat chicken should be treated in details. Therefore, this new technology needs further investigations to be validated.

Introduction

The microwave radiation is commonly used in the food industry to brown, to dry, to cook and to inactive microorganisms (Rosenberg and Bogl, 1987; Kakita *et al*., 1995; Hyland 1998; Woo *et al*., 2000; Yahmaee and Durance, 2005). This technology is also used in many house hold applications (Cha-um *et al*., 2009; Sakiyan *et al*., 2011). For pasteurization and sterilization, microwave heating is more preferred than conventional heating because it is faster and requires consequently less time to reach the required temperature (Laura and Noemi, 2010). Besides, this method is also considered to be efficient while regarding the energy consumption. Papadopoulou *et al.* (1995) have studied the bacterial effect of microwaves on certain pathogenic Enterobacteria and have reported differences between thermal and electromagnetic lethal effects. In a different study Virtanen *et al.* (1997) have proved that the microwave thawing reduces the processing time, the water loss, the microbiological problems and the chemical deterioration. In the meat industry, some analyses were driven by Taher and Farid (2001) to develop prediction models applicable to the chopped beef thawing. Shamis *et al*. (2008) have studied the effects of microwave treatment technique for bacterial decontamination of raw meat and finally Nagy *et al*. (2002) have shown that the treatment with microwave lengthen the beef shelf life products.

Currently, the poultry sector in Tunisa represents more than 9% of agricultural production, 25% of the livestock sector and provides 53% of all the provided meat. The productions have reached 9,608 tons in April 2012 against 8,374 tons in the same period of 2011 (African Manager, 2012). As part of the continuous improvement of quality management system and in order to accelerate the thawing process (4°C during 48 h) of poultry meat to meet the increased demand of Tunisian customers. This paper deals with the study of the effects associated with the use of an industrial microwave oven (20 kW/60 seconds). Different criteria were thus assessed such as microbiological, organoleptic and nutritional quality as well as thawing time and costs.

Materials and Methods

The thawing Material

An industrial microwave (Ferrite) of 25 kg as capacity was used during manipulation as well as sterile plastic bags. Foods temperature was measured

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by a digital thermometer (- 20°C to +150°C ± 0.1°C). The probe is stainless steel and 12.5 cm of long. Finally a pH meter especially designed for food (FC 202D electrode) was used with an accuracy of ± 0.1 unit of pH at 20°C to 25°C.

Sampling equipment

Sampling equipments are sterile. The sampler wears a gown, a cap, a mask and gloves. He is equipped with bags, labels and a cooler thermal insulation.

Colony counting apparatus

The Colony counting apparatus is equipped by a lighting system with a black background and provided with a magnifying glass to be used at a magnification of 1.5 times and an electronic counter. Incubators maintained inoculated media (boxes and bottles) within a temperature range of 30°C to 46°C.

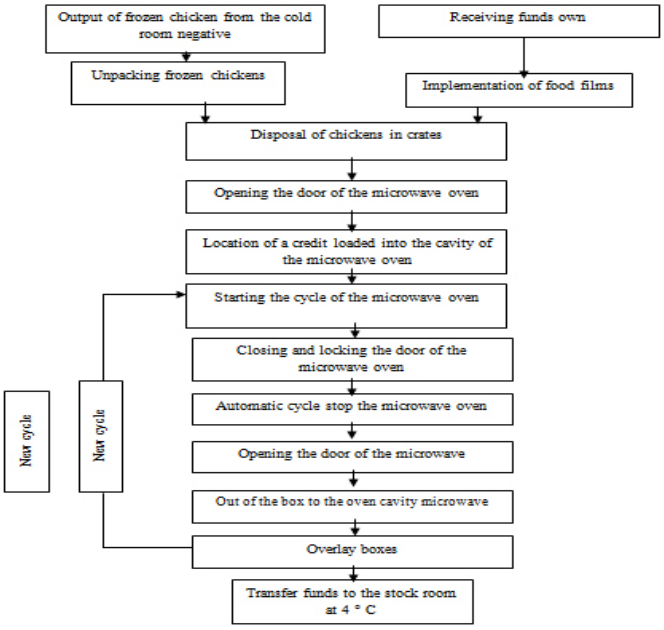

Figure 1. Diagram of thawing in the microwave oven

Thawing chicken

Thawing in cold positive

Twenty frozen chickens' of 1 kg each were maintained in plastic disinfected boxes at 18°C. In each box a single plastic wrap was introduced. 5 to 6 chickens were afterwards placed on the same level per box. Loaded boxes were then kept at the stocking room at 1°C to 3°C. An empty red box is put below all the loaded boxes without being in touch with the ground. The product is thawed for 48 hours at 4°C in a cold room according to the order of 06/26/1974. The latter cold room presented 30.3 m^3 of volume and is equipped with a compressor (K 280 CC.01 Dorin, 380 V and 6.5 A).

The microwave thawing

The microwave oven thawing was conducted similarly to the positive cold thawing. Once the boxes are loaded, they are placed one by one in the microwave oven cavity. The plannifed cycle lasts 60 seconds with a supplied power reaching 20 KW. Chickens have a temperature ranging from 4°C to 2°C. Subsequently, the boxes are stacked one upon the other with an empty red box below and returned to the stocking room to complete thawing for 15 hours. The process of thawing in the microwave oven is shown schematically in Figure 1.

Sampling and sample transport

Sampling of frozen products was done immediately after the release of negative cold room. For each test, a frozen chicken is collected, packaged, saddled, labeled and preserved at negative cold until being transported to the laboratory. The thawed product sampling was done after 15 hours of thawing in the microwave oven and after 48 h in positive cold. Sampling was done randomly by choosing a piece from the upper box and a piece from the bottommost box follwing the thawing process. Sampling was done in aseptic conditions. Each taken sample is introduced in a sterile bag, sealed and labeled. The samples thus prepared are placed in clean and sterile cooler, before being treated with alcohol and sent to be analysed.

Preparation of test samples

In the laboratory, a chicken is spread out in a stainless steel tray to obtain 10 g parts (7 g of flesh and 3 g of skin) which were collected aseptically. The sample is placed in a sterile stomacher bag after adding 90 ml of buffered peptone water. The whole is milled using a stomacher for 2 to 3 minutes. The obtained solution was diluted up to 10^{-5}. To search *Salmonella* spp., 25 g of the skin of the chicken are directly taken and diluted in 225 ml of buffered peptone water.

Bacteriological analysis

The enumeration of total mesophilic flora was done according to the ISO 2293 standards (1988) with the enumeration of microorganisms method colony count at 30°C. The enumeration of fecal coliforms was done according to the NF V 08-060 (2009), in which thermotolerant coliform by counting the obtained colonies at 44°C. The enumeration of *Staphylococcus aureus* was done according to ISO 6888-1 standards (1999), which is an horizontal method for the enumeration of coagulase positive staphylococci obtained by counting the colonies on

solid medium (Baird-Parker) after aerobic incubation at 35°C or 37°C. The enumeration of sulfite-reducing anaerobic in 46°C was done according to the NF V 08-061 (2009), and finally the detection of *Salmonella* was done according to ISO 6579 standards (2002).

Results and Discussion

Microbiological evaluation

At the starting point, it's important to mention that products examination basing on well defined indicators is simple, reliable and gives informations about the failures noted in a manufacturing process. In the case of food safety, the microbiological criterion is the most significant factor. The results of counting organisms (TMF, Fecal Coliforms, SRA, *Staphylococcus aureus* and *Salmonella*) in the upper boxes (Tables 1 and 2) and in the boxes placed in the bottom (Tables 3 and 4) are satisfactory and meet the standards according to the Order of December 21 (1979). Indeed, for the TMF level of the obtained seeds are significantly lower than 5 10^5 CFU/g. The results of fecal coliforms are below 10 CFU/g. This value is lower than the value set at 10^3 CFU/g. Similarly to the results of anaerobic sulphite reducing, the obtained rates in five weeks are less than 10 CFU/g and which are below the value set at 30 CFU/g. The results of *Staphylococcus aureus* are less than 50 CFU/g, and meet the standard (5 10^2 CFU/g). We also noted that all tests are free of Salmonella (absence in 25 g). Hence, it could be noted that according to the obtained results, the analysed product showed good manufacturing practices. Moreover, the obtained results by TMF under the two processes showed that the top boxes are more loaded with germs than those of the bottom. Indeed, the averages of TMF for slow process were 5.82 10^2 > 3.24 CFU/g (Tables 1 and 3) and for rapid process were 1.1 10^2 > 0.84 10^2 CFU/g (Tables 2 and 4). This difference is probably due to the temperature rise at the top boxes location. We suspect also the proliferation of bacteria adapted to this temperature as psychrophilic bacteria. Yet, the thawing time (48 h at 4°C) promotes the germination of the psychrophilic germs. In the microwave oven the products don't reach its thawing, at 4°C. This condition does not allow the proliferation of microorganism. This comparison allows us to reject the hypothesis of possible contamination of down or below boxes by the thawing water. Cling film deposited in the boxes before the introduction of frozen chicken served as insulators between the stacked boxes and as a barrier against the drainage of thawing water from one fund to another. The latter hypothesis proved that the risk of cross contamination by thawing water is controlled by the cling film. Yet, we noted that the average of TMF obtained over 5 weeks under the rapid process is lower than the slow process. Indeed, in upper cases (1.02 10^2 < 5.82 10^2 CFU/g) (Tables 1 and 2) and in cases located in the bottom (0.84 10^2 < 3.24 10^2 CFU/g) (Tables 3 and 4) the phenomenon is due to the effects of microwaves on inactivation of microorganisms. Similar results were published in several studies (Dreyfus and Chipley, 1980; Heddleson and Doores, 1994).

Table 1. Results of microbiological analysis of the upper boxes of thawed chicken in cold positive at + 4°C

Flora (CFU/g)	Sample Number					
	Week n°1	Week n°2	Week n°3	Week n°4	Week n°5	Average
TMF	10^3	6.10^2	10^3	3.10^2	10	5.82 10^2
Fecal Coliforms	<10	<10	<10	<10	<10	
SRA	<10	<10	<10	<10	<10	
S. aureus	<50	<50	<50	<50	<50	
Salmonella	Absent	Absent	Absent	Absent	Absent	

n=5

Table 2. Results of microbiological analysis of the upper boxes of thawed chicken in microwave oven

Flora (CFU/g)	Sample Number					
	Week n°1	Week n°2	Week n°3	Week n°4	Week n°5	Average
TMF	10^2	2.10^2	10^2	10^2	10	1.02 10^2
Fecal coliforms	<10	<10	<10	<10	<10	
SRA	<10	<10	<10	<10	<10	
S. aureus	< 50	< 50	< 50	< 50	< 50	
Salmonella	Absent	Absent	Absent	Absent	Absent	

n=5

Table 3. of microbiological analysis of the boxes from the bottom of thawed chicken in cold positive at +4°C

Flora (CFU/g)	Sample Number					
	Week n°1	Week n°2	Week n°3	Week n°4	Week n°5	Average
TMF	10	5.10^2	10^3	10^2	10	3.24 10^2
Fecal coliforms	<10	<10	<10	<10	<10	
SRA	<10	<10	<10	<10	<10	
S. aureus	< 50	< 50	< 50	< 50	< 50	
Salmonella	Absent	Absent	Absent	Absent	Absent	

n=5

Table 4. of microbiological analysis of the boxes from the bottom of thawed chicken in microwave oven

Flora (CFU/g)	Sample Number					
	Week n°1	Week n°2	Week n°3	Week n°4	Week n°5	Average
TMF	10	10^2	2.10^2	10^2	10	0.84 10^2
Fecal coliforms	<10	<10	<10	<10	<10	
SRA	<10	<10	<10	<10	<10	
S. aureus	<50	<50	<50	<50	<50	
Salmonella	Absent	Absent	Absent	Absent	Absent	

n=5

Assessment of sensory quality

For consumers, appearance is the major criterion for purchase, selection and initial evaluation of meat

quality (Allen *et al.*, 1997). The most two important quality attributes for poultry meat are appearance and texture (Fletcher, 2002). According to Mendes *et al.* (2001), the selection of carcass quality is usually based on visual criteria. The freshness of meat chicken was monitored by means of colorimetric sensory array (Salinas *et al*., 2012). During the last two decades, a number of methods have been developed to objectively measure meat quality attributes. In addition, reduced product quality results in reduced consumer acceptance (Kotula and Padya, 1995; Lee *et al*., 1996). Based on the works of Allen *et al.* (1997), Fletcher (2002) and Mendes *et al.* (2001), in the present study a visual monitoring is practiced by a trained descriptive panel composed with 6 participants. A previously developed meat lexicon composed of 10 terms (bluish color, pinkish color, viscous skin, shade of cooked, number of blue spots, number of pinkish spots, chicken farm, chicken flange, width of the spot, depth of the spot) was choosen by the management team. During 7 days, in a tasting room at 18°C, each participant evaluated 12 chickens (6 chickens each process). Concerning the slow process, the participants were unanimous in noting the loss of freshness and if chickens are flabby. The blues spots (1 or 2 spots/chicken) were noted in some chicken with no specific location. The participants were also unanimous in noting that the spots are external. The spots are probably due to the touch of chicken during thawing process (48 hours). However, the odors and blue spots have not reaped unanimous jury. Unanimously, the participants noted that the viscous liquid and glossy which is presumably rich in nutrients enveloped the carcass. Indeed, the exudation of chickens under slowly process is very important which probably causes a loss of nutrients and the weight of the chicken. Concerning the rapid chicken process, some participants noted that deep and small spots (narrower than the blue spot) with a pink color (color of cooked area) were observed on some chickens (more than two spots per chicken) and are located especially on the thighs. Probably, the mainly cause could be the power of microwave. The panelists noted that the spots are located on the skin and on the flesh. However, the participants noted that the pinkish color recalls the color of the fresh product and the chicken retains its firmness. Under the rapid process, the panelists noted neither weight loss nor significant exudation in chicken. In conclusion, according to the panelists, the organoleptic quality of product by accelerating process is better preserved than the slow process. It has been reported in the literature that the microwave has a potential to keep the product fresh. According to Pereira and Vicente (2013), meat is a valuable source of high biological value protein, irons Vitamin B12 and has exerted a crucial role in human evolution and is an important component of a health. In this sense, we must ensure the safety food quality for consumers according to the Official Journal of the Tunisian Republic (1992) (Law n°92-117, 1992; consumers protection) and the Official Journal of the Tunisian Republic (1985) (Law N°58, 1985). Thus, the assessment of nutritional value and sensorial changes for chicken meat under accelerating process must be studied using an appropriate sensorial scheme such as quality index method (QIM), by biochemical and chemical methods especially the changes in biochemical properties of myofibrillar proteins in cooked areas.

Evaluation of thawing time

MW drying offers opportunities to shorten the drying time and improves the quality of the dried products (Zhang *et al*., 2006). Our results clearly indicate that 48 hours is enough for 20 kg of chickens. However, 15 h is sufficent in the case of the microwave allowing thus to save 33 h. Similar time save by microwave was reported by Campanone and Zaritzky (2005). In general, MW-related drying can meet the four major requirements in drying of foods such as speed of operation. In conclusion, the thawing microwave allows reducing 33 h of the process duration. Consequently, in terms of economic profitability, this method allows us to sell 3 times more chickens than the slow method.

Risk assessment

Consumers demand high quality, natural, nutritious, fresh appearance and convenient meat products with natural flavor and taste and finally an extended shelf life. However, Several international bodies, such as the Codex Alimentarius Commission of the World health Organization (WHO), the Food and Agricultural Organization (FAO), the International Organization of Microbiologic Specifications for Foods (ICMSF), the World Trade Organization (WTO), the Agreement of sanitary and phyto sanitary Measures (SPC) and the Technical Barriers to trade (TBT) have developed and provided guidelines for the equivalency in International standards to protect the health of consumers and ensure fair practices in food trade (Bilgili, 1999).

We note that the consistency of chicken meat thawed in cold positive becomes softer with time and uniformly in the whole carcass. However, the consistency of chickens is not homogeneous under accelerating process. Indeed, the wings and the rish fat parts remain frozen and hard, while the thighs

are tender and easy to cut. So, temperature is not uniform in different parts of the carcass. Some parts of the chicken keep a negative temperature while for example thighs reach a positive temperature. It's noteworthy to mention that the latter phenomenon was reported in several researchs (Lin *et al.*, 1995; Zhou *et al*., 1995). Temperature distribution studies during microwave heating have been conducted by Vadivambal and Jayas (2010). They conclude that the major drawback associated with microwave heating is the non uniform temperature distribution resulting in hot and cold spots in the heated product. We noted that some areas of the carcass are cooked. This defective meat is the major risk of this new technology which could cause the rejection of the chicken by consumers.

To the consumers, appearance is the major criterion for purchase selection and initial evaluation of meat quality. However, according to Fletcher (2002), the two most important quality attributes for poultry meat are appearance and texture. According to Mendes *et al.* (2001), the selection of carcass quality is usually based on visual criteria. MW drying alone has some major drawbacks that include uneven heating, possible textural damage, and limited product penetration of the MW radiation into the product. Among the chemical risks that might be associated with the microwave cooking we should mention the protein denaturation and the molecular structure modification upon heating. The degradation rates depend on the heating time and temperature. Another defect is to take into consideration the temperature distribution in the chicken. Manickavasagan *et al.* (2009) studied the temperature rise and distribution in ready to eat (RTE) chicken pie after microwave heating in three domestic ovens. They proved that an irregular heating pattern with hot and cold regions was observed on the surface and inside the pie. The difference between maximum and minimum temperatures was in the range of 31.6 to 130.58°C on the surface and 10.7 to 76.18°C inside the pie. According to the obtained results in this study, we noted that the mainly defect is the cooked areas of the carcass (defective meat). Probably, the proteins are denatured with the modification in molecular structure upon heating. We note that some of cooked chickens are rejected (unsold) by the consumers. The loss is considerable compared to the slow process. Indeed, 25% of chickens are lost when using the rapid method. Thus, to satisfy the customers and to maintain a brand image, a customer satisfaction survey is implemented and future investigations for thawing poultry meat at 0.75 min and 1.5 min are being planned.

Cost evaluation

By slow process, the thawing cycle of poultry meat lasts 48 h at 4°C. The energy consumption (cold room) is 2.47 kw/h. Thus, the total consumption of energy/cycle is 118.56 kw. However, the cycle of accelerating thawing process lasts 60 s and 15 h (60 s in microwave and 15 h at 4°C). Thereby, the consumption of energy by the accelerating process during one cycle is 20 kw/60 s + (15 h*3 kw). Therefore, the total consumption is 70 kw/cycle. Accordingly, we noted that the accelerating process minimizes both: energy (118.56 kw-70 kw = +48.56 kw) and time (48 h-15 h = +33 h). However, oven requires a workforce that needs to be qualified, responsible and confident. The device runs on electrical energy and demand maintenance in case of breakdown. All these costs must be subsequently studied to estimate the losses and gains that a given company may have.

Conclusion

In order to validate the application of microwave oven (accelerating process) for poultry meat chicken, we compared the accelerated thawing process and the slow thawing process (48/4°C) following well established criteria. Thawing time and cost data indicated that the accelerated process is more profitable than the slow one. However, according to the sensory evaluation, the results are conflicting. Remarquably, the microwave oven has a potential to keep product fresh. Indeed, the chicken retains its firmness. The assessment panel noted particularly the texture defects. The latter damage might be considered as the major risk. Finally, this method needs further investigations to improve all the porcess parameters' such as time and energy consumption by cycle.

References

African Manager. 2012. Tunisia: Production of 9608 tons of poultry meat in April 2012. Published in the African Manager 05/07/2012.

Allen, C.D., Russell, SM. and Fletcher, D.L. 1997. Threlation ship of broiler breast meat color and pH to shellife and odor development. Poultry Science 76: 1042–1046.

Bilgili, SF. 1999. Assuring the safety of poultry products in a global market: The US perspective. XIV European Symp on the Quality of Poultry Meat. Bologna, Italy: 513-519.

Campanone, L.A. and Zaritzky, N.E. 2005. Mathematical analysis of microwave heating process. Journal of Food Engineering 69 (3): 359-368

Cha-um, W., Rattanadecho, P. and Pakdee, W. 2011. Experimental and numerical analysis of microwave heating of water and oil using a rectangular wave guide:

Influence of sample sizes, positions, and microwave power. Food and Bioprocess Technology 3: 813–825.

Dreyfuss, M.S. and Chipley, J.R. 1980. Comparison of effects of sublethal microwave radiation and conventional heating on the metabolic activity of *Staphylococcus aureus*. Applied and Environmental Microbiology 39 (1): 13-16.

Fletcher, D.L. 2002. Poultry meat quality. World's Poultry Science Journal 58: 131-145.

Heddleson, R.A. and Doores, S. 1994. Factors affecting microwave heating of foods and microwave induced destruction of food borne pathogens – a review. Journal of Food Protection 57 (11): 1025-1037.

Hyland, G.J. 1998. Non-thermal bioeffects induced by low intensity microwave irradiation of living systems. Engineering Science and Education Journal 7(6) : 261-269.

ISO 2293. 1988. Meat and meat products-Enumeration of micro-organisms-Colony count at 30°C (Reference method).

ISO 6579. 2002. Microbiology of food and animal feeding stuffs-Horizontal method for the detection of *Salmonella* spp.

ISO 6888-1. 1999. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species) - Part 1: Technique using Baird-Parker agar medium.

Kakita, Y., Kashige, N., Murata, K., Kuroiwa, A., Funatsu, M. and Watanabe, K. 1995. Inactivation of *Lactobacillus* bacteriophage PL-1 by microwave irradiation. Microbiology and Immunology 39 (8): 571-576.

Kotula, K.L. and Pandya, Y. 1995. Bacterial contamination of broiler chickens before scalding. Journal of Food Protection 58: 1326-1329.

Laura, A.C. and Noemi, E.Z. 2010. Mathematical Modeling and Simulation of Microwave Thawing of Large Solid Foods Under Different Operating Conditions. Food and Bioprocess Technology 3: 813–825.

Lee, J.I., Shin, E.H., Kim, C.R. and Kim, K.H. 1996. Reducing microbial populations on refrigerated pork harms treated with acetic acid. The Korean Journal of Food And Nutrition 9: 484.

Lin, Y.E., Anantheswaran, R.C. and Puri, V.M. 1995. Finite element analysis of microwave heating of solid foods. Journal of Food Engineering 25 (1): 85–112.

Manickavasagan, A., Jayas, D. S., Vadivambal, R. 2009. Nonuniform microwave heating of ready-to-eat chicken pies. Canadian Biosystems Engineering 51: 3-39.

Mendes, A.A., Moreira, J., Garcia, R.G., Naas, I.A., Roça, R.O., Iwamura, M., Oliveira, E.G. and Almeida, I.G.L. 2001. Avaliação do rendimento e qualidade da carne de peito em frangos de corte criados com diferentes densidades e níveis de energia na dieta. Rev Bras Ciência Avícola supl 3: 38.

Nagy, H.A., Suzan, R.M. and Bouthaina, M.Y. 2002. Effect of gamma ray and microwave treatment on the shelf-life beef products stored at 5°C. Food control 13 (6-7): 437-444.

NF V08-060. 2009. Food microbiology. Enumeration of thermotolerant coliform colony count obtained 44 °C.

NF V08-061. 2009. Food microbiology. Enumeration of anaerobic sulfate-reducing bacteria using colony count at 46°C.

Official Journal of the Tunisian Republic. 1985. (O J T R) 1985 No. 58. Order of the Minister of the Tunisian economy on the homologation of the Tunisian standard for the labeling and presentation of Prepackaged Foods. 1012-1013.

Official Journal of the Tunisian Republic. 1992. (O J T R) 1992 No. 83: Law No. 92-117 on December 7 relating consumer protection. 1571-1574.

Ogunbanwo, S.T. and Okanlawon, B.M. 2006. Microbial and sensory changes during the cold storage of chicken meat treated with Bacteriocin from *L. brevis* OG1. Pakistan Journal of Nutrition 5 (6) : 601-605.

Order of 21December 1979. 1979. Order of 21 December 1979 on microbiological criteria required for some animal products.

Papadopoulou, C., Demetriou, D., Panagiou, A., Levidiotou, S., gessouli, H., Ioannides, K. and Antoniades, G. 1995. Survival of Enterobacteria in liquid cultures during microwave radiation and conventional heating. Microbiological Research 150 (3): 305–309.

Pereira, P.F. and Vicente A.F. 2013. Meat nutritional composition and nutritive role in the human diet. Meat Science 93 (3): 586-592.

Rosenberg, U. and Bogl, W. 1987. Microwave pasteurization, sterilization, blanching, and pest control in the food industry. Food Technology 41 (6): 92–99.

Sakiyan, O., Sumnu, G., Sahin, S., Meda, V.,Koksel, H. and Chang, P. 2011. A study on degree of starch gelatinization in cakes baked in three different ovens. Food and Bioprocess Technology 4: 1237–1244.

SalinasY., Ros-Lis J.V.Vivanco J.L, Martinez-Manez R., Marcos M.D., Aucejo S., Herranz N. and Lorrente I. 2012. Monitoring of chicken meat freshness by means of a colorimetric sensor array. Analyst 137 (16). 3635 - 3643.

Shamis, Y., Taube, A., Shramkov, Y., Mtik-Dinevan, M., Vu, B. and Ivanova, E.P. 2008. Development of Microwave treatment Technique for bacterial decontamination of raw meat. International Journal of Food Engineering 4: 379-389

Taher, B.J. and Farid, M.M. 2001. Cyclic microwave thawing of frozen meat experimental and theorical investigation. Chemical Engineering and Processing: Process Intensification 40 (4): 379-389.

Vadivambal, R. and Jayas, D.S. 2010. Non-uniform Temperature Distribution During Microwave Heating of Food Materials – A review. Food and Bioprocess Technology 3: 161–171.

Virtanen, A., Goedeken, D. and Tong, C. 1997. Microwave Assisted Thawing of Model Frozen Foods Using Feed-back Temperature Control and Surface Cooling. Journal of Food Science 62 (1): 150–154.

Woo, I.S., Rhee, I.K. and Park, H.D. 2000. Differential

Damage in Bacterial Cells by Microwave Radiation on the Basis of Cell Wall Structure. Applied and Environmental Microbiology 66 (5): 2243-2247.

Yahmaee, P. and Durance, T.D. 2005. Destruction and injury of *Escherichia coli* during microwave under vacuum. Journal of Applied Microbiology 98 (2): 498-506.

Zhang, M., Tang, J., Mujumdar, A.S. and Wang, S. 2006. Trends in microwave-related drying of fruits and vegetables. Trends in Food Science and Technology 17: 524-534.

Zhou, L., Puri, V.M. and Anantheswaran, R.C. 1995. Finite element modeling of heat and mass transfer in food materials during microwave heating-Model development and validation. Journal of Food Engineering 25(4): 509–529.