Improvement of quality and shelf-life of chicken breast after ozonization and partial dehydration

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Abstract. *In this research, the efectiveness of gaseous ozonization and partial dehydration as combined preservation methods to improve quality and shelf-life of chicken breasts were tested. No previous work has been done combining both techniques applied on meats.*

Likewise, the conditions for ozonizing and partially dehydrating chicken breast had already been optimized separately by our team.

The optimized conditions for ozonization and partial dehydration were different from those ones that were determined using the two techniques separately. In case of ozonization, time of treatment had to be reduced by half, whereas time of dehydration could be kept the same as well as the rest of process parameters, in order to get a new product that was acceptable sensorially and from the microbiological point of view to ensure extended shelf-life of treated chicken breasts over one month under refrigeration at 1-2ºC.

On the other hand, the advantages of using ozone combined with partial dehydration are shown, in order to make the consumption of poultry breast safer, longer-lasting and more acceptable to consumers. The aim is to get enough safety factors on our product in order to guarantee that, if one inhibitor factor is lost or not effective, the rest of factors will keep the new product safe.

Keywords. Chicken, dehydration, ozone, preservation methods.

Introduction

In the European Union, the consumption of meat is very important and this tendency is increasing. For this reason, along with meat being often the cause of human poisoning and when there is a certain lack of consumer confidence in meat products, it is necessary to produce "safer meat".

Ozone is a very powerful oxidizing agent, which main biocidal action may be due to oxidation of fatty acid double bonds in cell walls and plasma membranes, thus causing changes in cell permeability, which leads to cell lysis. Nevertheless, the exact disinfection mechanism of ozone is still not clear (National Research Council, 1987).

Due to the fact that ozone is a very unstable gas, it has to be generated on-site, close to the point of use. Ozone can be generated by splitting oxygen molecules into oxygen atoms, which react with molecular oxygen to form ozone (Khoudary, 1985).

In Europe, ozone has been mainly used in waste water treatment (Venosa, 1972) and it can also be used to disinfect poultry chill water for recycling (Sheldon & Brown, 1986; Chang & Sheldon, 1989; Adams, 1990; Waldroup *et al.*, 1993). Regarding the microbiological effectiveness of ozone for disinfecting broiler carcasses, the reported results in bibliography are controversial, since it is not clear whether ozone has a positive effect on reducing microbial load and extends the shelf-life of broiler parts under refrigeration (Yang & Chen, 1979), or, on the contrary, it is not an effective preservation method for poultry carcasses (Sheldon & Brown, 1986).

On the other hand, dehydration is one of the most extended methods to preserve different kinds of foods, lyophilization and partial dehydration being mainly used. Lyophilization is very expensive, but the quality of lyophilized products is really good; whereas partial dehydration is cheaper, as the drying time of controlled low-temperature vacuum dehydration (partial dehydration) is shorter and lower energy is consumed than that of freeze-drying. Therefore, partial dehydration is a drying method which might overcome some of the problems caused by freeze-drying (King *et al.*, 1989; King & Su, 1993). For instance, lipid oxidation is one of the primary mechanisms of quality deterioration in foods, especially meat products (Gray *et al.*, 1996; St Angelo, 1996). The surface area of partially dehydrated products is less than that of freeze-dried ones, therefore, oxidation should be diminished.

The main objective of the following study was to determine the efficacy of using ozone and partial dehydration as combined preservation methods to improve quality and shelf-life of chicken breasts.

Materials and Methods

Sample preparation

The raw Broiler chickens used were provided by several farms from Northern Spain and transported, slaughtered and stored under refrigeration by “Pollos Iriarte S.A.” Company, who controlled chickens from origin: Duration of transport between farm and slaughter, handling conditions, age, weight and feed of chickens. The chicken meat was trimmed of any defect and stored at 4ºC for less than three days. The average water content and water activity of fresh samples were 73.2± 0.9% and 0.982± 0.001 respectively, being the pH 5.5-5.7.

For the experiments, boneless *Broiler* chicken breasts were cut into different thickness slices and pieces of 70x40 mm^2 surface before being ozonized and partially dehydrated.

Ozone-producing and partial dehydration systems

A gaseous ozone-producer equipment, Rilize 3060 model, coupled to a Rodax type ozone-meter, as well as a vacuum dehydration equipment were used.

A pilot scale vacuum dryer (Telstar model VC) with pressure control was used. Inside the vacuum chamber, temperature sensors (Pt 100- 2 4 wire) were used to measure environmental and temperature of samples. Also a balance (Dentor precision 0.01g) was available. An infrared lamp (maximum power 400 w) placed at the same distance from the sample was used as a heater to accelerate the speed of dehydration process. Temperatures and sample weight could be read online in a display. In Fig. 1, the apparatus used for partial dehydration is represented.

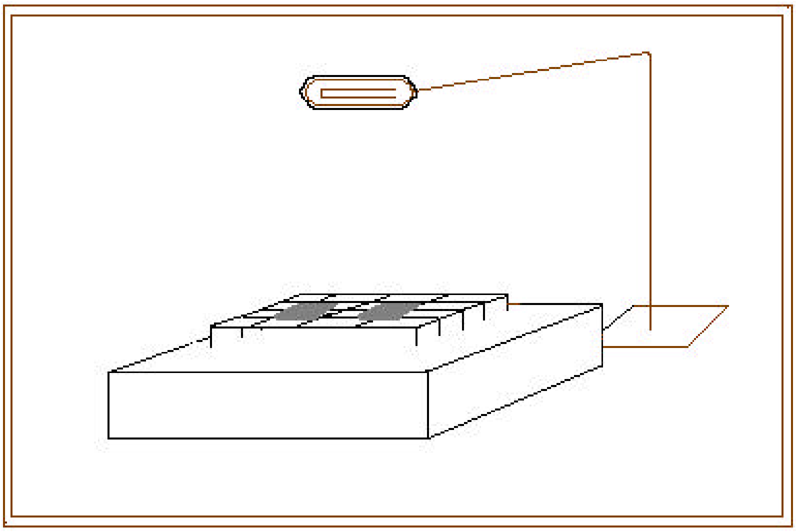

Figure 1. Experimental setup.

Experimental procedures

Preliminary experiments were performed to determine the conditions for ozonizing and partially dehydrating chicken breast, both techniques having been optimized separately by our team.

Samples were ozonized first and then partially dehydrated. Afterwards, they were vacuum packed and stored at 1º-2º C. The dose of ozone used was the same in all cases and three different application times (20, 60 and 120 minutes) were assayed.

Regarding partial dehydration, several analyses were carried out in order to determine the following process parameters: vacuum pressure in the chamber, heat power of the lamp and application times to be assayed for the chicken slices. In each dehydration experiment, two chicken slices were dried simultaneously at the corresponding treatment conditions.

Drying curves were obtained in order to study the sample weight losses and temperature evolution during the different conditions of the partial dehydration process, as sensory and nutritive characteristics of the product may be affected by temperatures above 40ºC and 55ºC, that could reduce the water holding capacity –WHC- and could also affect some chicken proteins, respectively.

Immediately after the experiments, microbiological counts, appearance, water activity (a_w), water content, weight loss and pH of the sample were analysed. The remaining samples were vacuum packed and stored at 1-2ºC until physical and chemical analyses (content of proteins and ash, degradation of fats and proteins), instrumental (colour, texture) and sensorial analyses were performed on fresh and treated meat.

The experiments were done by triplicate.

Table 1.- Times of experiments for partial dehydration with and without a heating source.

	Pressure= 12 mb		Pressure= 100 mb	
Time (min)	Slab 3 mm	Slab 8 mm	Slab 3 mm	Slab 8 mm
Without heating source	40, 80, 120	40,80,120	40,80,120	40, 80, 120
With heating source	40, 80, 120	40,80,120	----	---

Microbiological Analyses

The analyses of mesophilic aerobic bacteria, *Staphylococcus aureus* enteropathogenic, *Clostridium spp*., Psycrotrophic bacteria, total coliforms, *Escherichia coli*, *Lactobacillus spp*., Moulds and Yeast, were performed on fresh and treated meat, and the methods used were based on official methods. The analyses of *Salmonella spp.* was only determined on fresh meat .

Physical and Chemical Analyses

The water content of the samples was determined by drying at 103± 2ºC until reaching constant weight (AOAC, 1980).

Ashes were determinated by sample incineration in an oven at 550ºC (AOAC, 1975),

Protein content was obtained by Nitrogen quantification by Kjeldahl method (Pearson, 1998).

The Conway microdiffusion technique was used to determine the protein degradation index (Pearson, 1998). Fat degradation index was estimated by measuring the free fatty acid content and the peroxide index (Pearson, 1998).

Instrumental Analyses

Water activity was measured by an electronic hygrometer NOVASINA a_w box, whereas pH was measured by a plunger pH-meter.

The texture was evaluated through the chewing force obtained by a TA-XT2i Texture Analyzer equipped with a Kramer cell. The peak of the force curve was used as a texture indicator.

The processed chicken slices were subjected to colour measurements using a spectrophotometer Minolta 2500-d and the CIE 1976 L*a*b* system was used.

Sensory Analyses

The sensorial characteristics of the samples were analysed by trained members of the research team, who evaluated the percentage of surface discoloration, chicken odour, odour characteristics and overall aspect. Therefore, a 7 point scale was used for the first three characteristics, whereas a 5 point scale was used to evaluate aspect of fresh and treated meat.

The determination of shelf-life was mainly estimated through sensory evaluation and also microbiological assays and degradation of proteins and fats.

Statistical Analyses

The data were also analysed statistically by analyses of variance ANOVA, regression analyses and full factorial analyses by *Statgraphics Plus*.

Results and Discussion

Determination of optimal conditions for ozonization and dehydration applied separately

Ozonization

The effect of ozone is changeable depending on concentration and time of treatment, as they are the main factors that affect quality and shelf-life of chicken breasts.

Two concentrations of ozone were assayed (an intermediate level and the highest level produced by the ozone-generator), combined with three different times (20, 60 and 120 minutes). The highest concentration of ozone as well as the longest time of treatment was the best combination, as a significant reduction of microbial load was reached, especially being affected Gram negative microorganisms -total coliforms and *E. coli*- on breasts. On the other hand, samples were also sensorially acceptable.

Partial dehydration

In order to preserve the quality of partially dehydrated chicken breasts, the maximum temperature at the surface of the sample during the process was 35º C approximately.

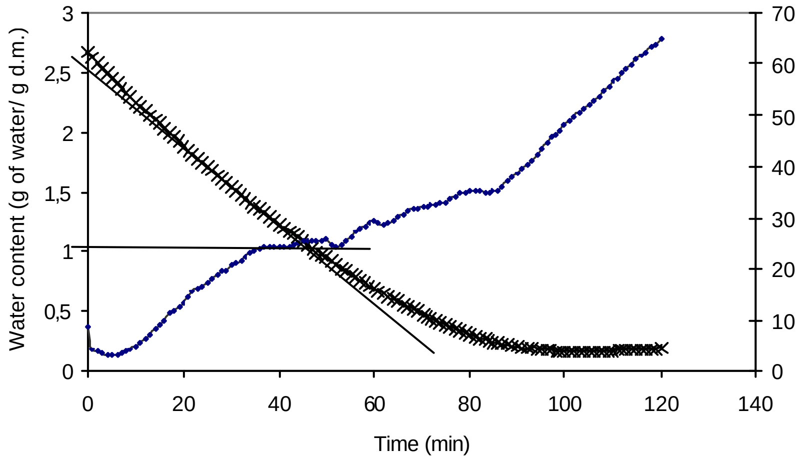

Figure 2. Drying curve of chicken breast.

From the obtained results of water content, a_w and aspect after partial dehydration experiments (Table 2) without the infrared lamp, the following phenomena were observed:

- As treatment time increased, the water content and a_w decreased.
- The slice thickness affected significantly the water content and appearance.

Table 2.- Water content, a_w and appearance of partial dehydration chicken slices of 40x70 mm^2 area, with no heating source.

Time (min)	Pressure= 12 mb - With no heating lamp					
	Slab 3 mm			Slab 8 mm		
	W (%)	Aw	Aspect	W (%)	Aw	Aspect
40	62.99± 8.06	0.976± 0.001	-	68.61± 1.86	0.970± 0.004	+
80	62.72± 3.23	0.975± 0.002	-	66.5± 0.9	0.947± 0.003	+
120	55.96± 1.06	0.973± 0.002	-	68.02± 8.06	0.965± 0.001	+

From the obtained results of water content, a_w and appearance after partial dehydration experiments (Table 3) with the infrared lamp, the following phenomena were observed:

- As treatment time increased, the water content and a_w decreased. Significant differences were shown for a_w values when time was increased from 80 to 120 minutes.
- The slice thickness affected significantly the water content, a_w and appearance.
- The application of heat didn't affect significantly the a_w.

Table 3.- Water content, a_w and appearance of partial dehydration chicken slices of 40x70 mm^2 area, with a heating source.

Time (min)	Pressure= 12 mb - With a heating lamp					
	Slab 3 mm			Slab 8 mm		
	W (%)	Aw	Aspect	W (%)	Aw	Aspect
40	73.93± 0.17	0.952± 0.007	-	70.55± 0.19	0.971± 0.001	+
80	----	----	-	66.58± 0.28	0.972± 0.001	+
120	----	----	-	73.5± 0.44	0.962±0.002	+

The pH of the samples was not significantly affected by the partial dehydration process in the assayed conditions. The appearance was considered unacceptable, when 3 mm- thickness slices of chicken samples were used.

The reduction of chicken water content, water activity and the increase of temperature at the surface of the samples augmented when an infrared lamp was used to accelerate the dehydration process, and also when the slices thickness decreased.

Therefore, the selected conditions for partial dehydration were the following ones: 8 mm – thickness slab, pressure of 12 mb with a heating source and the longest time of treatment.

Determination of optimal conditions ozonization and dehydration applied in combination

Keeping the highest concentration of ozone produced by the ozone-generator, when each preservation treatment was applied separately, the longest time for both processes (120 minutes) was best, as a significant reduction of microbial load and water activity content on breasts was reached and samples were both sensorial and microbiologically acceptable. Nevertheless, time for ozonization had to be reduced by half (60 minutes) and kept the rest of process parameters the same, in order to get combined treatments improved colour (*a*- value), firmness and overall impression of the breasts.

There were no significant differences between fresh and treated meat relating to either protein degration or fat degradation, which pointed out that the combined preservation treatments didn´t change much the microstructure of meat.

Likewise, the shelf-life of treated meat was over one month, in comparison with raw chicken breast stored at 1-2º C. After both treatments, from the 32^{nd} day onwards, the counts of psychrotrophic microorganisms (*Pseudomonas* spp, *Lactobacillus spp*...) were unacceptable and, sensorially, breasts had discoloration and a slightly bad smell.

The worst conditions were the lowest time for both treatments (20 minutes of ozonization and 40 minutes for partial dehydration), either separately or applied in combination, as those conditions affected quality of products very negatively and reduced shelf-life of products dramatically.

Conclusions

The use of gaseous ozone combined with partial dehydration has a positive effect on poultry breasts, as a safer, longer-lasting and more acceptable product to consumers was obtained.

The conditions for both preservation methods, when applied in combination, were improved by reducing by half the time for ozonization.

Time of treatment is one of the most important parameters that affects both ozonization and partial dehidration and it is a very critical factor to reach the best preservation conditions for poultry breasts.

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References

Adams, M.H. 1990. Effects of ozonated chill water on microbiologicall and sensory characteristics of broiler carcasses and on quality of of chill water. M.S. Thesis, University of Arkansas, Fayetteville, AR.

Chang, Y.H. and B.W. Sheldon (1989). Application of ozone with physical wastewater treatments to recondition poultry process waters. *Poultry Sci*. 68: 1078-1087.

Gray, J.I., Gomaa, E.A., and Buckey, D.J. (1996). Oxidative quality and shelf-life of meats. *Meat Sci.* 43 (Suppl.): 111-123.

Khoudary, N. 1985. Sterilization fundamentals of ozonation. *Ultrapure Water*, January/February, p.30.

King, V.A.E., and Su, J.T. (1993). Dehydration of *Lactobacillus acidophilus*. *Process Biochem.* 28: 47-52

King, V.A.E., Zall, R.R., and Ludington, D.C. (1989). Controlled low-temperature vacuum dehydration – a new approach for low-temperature and low-pressure food drying. *J. Food Sci.* 54: 1573-1579, 1593.

National Research Council. 1987. *Drinking water and health*. Volume 7. Natl. Acad. Press, Washington, DC.

Sheldon, B.W., and A.L. Brown. 1986. Efficacy of ozone as a disinfectant for poultry carcasses and chill water. *J. Food Sci.*, 51: 305-309

St Angelo, A.J. (1996). Lipid oxidation in foods. *Crit. Rev. Food Sci. Nutr.* 36 (3): 175-224.

Venosa, A.D. 1972. Ozone as a water and a wastewater disinfectant: A literature review. In *Ozone in water and waterwaste treatment*, 83-100. F.L. Evans, ed. Ann Arbor Sci. Publ., Inc., Ann Arbor, MI.

Waldroup, A.L., R.E. Hierholzer, R.H. Forsythe, and M.J. Miller. 1993. Recycling of poultry chill water using ozone. *J. Appl. Poultry Res.* 2: 330-336.

Yang, P.P.W., and T.C. Chen. 1979. Effects of ozone treatment on mycoflora of poultry meat. *J. Food Process. Preserv.* 3:177-185.