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Study of modified atmosphere packaging on the quality of ozonated freeze-dried chicken meat

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ABSTRACT

The objective of this study was to evaluate the effects of different modified atmosphere packaging (MAP) conditions on the physicochemical and sensory properties of ozonated freeze-dried chicken meat stored at 21 ± 1 °C for 28 days. To this end, 14 MAP treatments were performed to obtain the most suitable packaging atmosphere. High concentrations of O_2 in MAP promoted loss of redness and increased the pH values. Moreover, when the concentration of CO_2 in MAP was more than 40%, high values of textural parameters and low scores of sensory hardness and chewiness were achieved. The 20%CO_2/80%N_2 gas combination was found to be the most effective treatment for best maintaining the physicochemical and sensory quality of ozonated dried chicken samples similar to that of raw meat.

1. Introduction

Poultry meats are widely consumed freshly in Europe, but in fact they are highly perishable to bacterial contaminants due to their composition, a high water activity (a_w), and a high final pH, limiting the shelf-life of the products. Spoilage of fresh poultry products is an economic burden to the producer (Petrou, Tsiraki, Giatrakou, & Savvaidis, 2012); so, developing effective hurdle technologies to extend the shelf-life and to keep the product quality during long periods represents a major task for the poultry processing industry. According to Cantalejo, Zouaghi, and Pérez-Arnedo (2016), the combined effect of gaseous ozone and lyophilisation in chicken breast meat showed great antimicrobial effectiveness, due to the action of ozone; as well as the low percentage of humidity (<10%) and water activity (<0.5) of the product after freeze-drying prevented the microbial growth on the samples. These techniques also allowed extending the shelf-life of those products during 8 months of storage at room temperature without refrigeration. However, the combination of those hurdles were not sufficient to maintain the physicochemical (texture) and sensory qualities of the ozonated dried meat for long time.

In fact, the loss of textural qualities (i.e., tenderness and juiciness) was the main problem in freeze-dried meats, maybe due to denaturizing of proteins (Babić, Cantalejo, & Arroqui, 2009). Hence, as a result of an increasing demand for healthy and high-quality products, a need emerged for further research work involving the possibility of maintaining better sensory quality of ozonated freeze-dried chicken meat to reach more potential markets and satisfy consumer demands, hardness and juiciness being some of the main criteria influencing consumer's acceptability (Ganhão, Morcuende, & Estévez, 2010; Szczesniak, 2002). According to Babić et al. (2009), the freeze-dried meat products which have been adequately packaged can be stored for unlimited periods retaining the majority of their physical, chemical, biological and sensory properties as in the fresh state.

In this context, modified atmosphere packaging (MAP) has been considered in this study as a useful technique to maintain the sensory quality and to extend the shelf-life of several food commodities, including chicken meat (Chouliara, Karatapanis, Savvaidis, & Kontominas, 2007). García-Esteban, Ansorena, and Astiasarán (2004) stated that modified atmosphere packaging preserved meat (i.e. dry-cured ham) from hardening and deterioration of textural properties more efficiently than vacuum packaging. The principle of MAP is the replacement of the atmosphere surrounding a product before sealing, carbon dioxide, oxygen and nitrogen, being the most commonly used gases. Carbon dioxide possesses bacteriostatic activity (Nair, Kiess, Nannapaneni, Schilling, & Sharma, 2015). Oxygen is important to retain meat color and nitrogen results essential to avoid oxidation of fats and pack collapse. These gases can be applied individually or in combination, in order to achieve an optimum effect, depending on the specific needs of the particular food products being preserved (Narasimha Rao & Sachindra, 2002).

Therefore, the aim of this study was to evaluate the effects of MAP conditions on the physicochemical and sensory properties of ozonated freeze-dried chicken meat stored at room temperature, in order to obtain a new raw high-quality meat product with no preservatives and stable over time at room temperature. Also, the new raw products

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from fresh poultry meat represent an alternative, as they would allow a length in the retail period in the case of natural catastrophes, military campaigns, export to third countries, scarcity in electricity supply, etc. This is the first time that these three combined techniques (ozonation, freeze-drying and MAP) have been applied on poultry meats.

2. Materials and methods

2.1. Samples preparation

Broiler chicken breast meat was provided by U.V.E., S.A. Company (Tudela, Navarre, Spain). Chickens were 42 days old before slaughtering with approximately 2 kg of weight. All breasts were stored in a refrigerated room (2–4 °C) for the time of reception until used. The initial load of total aerobic mesophilic bacteria (TAMB) (<5 log cfu/g), lactic acid bacteria (LAB) (<4 log cfu/g), *Escherichia coli* (<2 log cfu/g) and *Salmonella* spp. (not detected in any of the chicken samples) was determined before samples were processed. The samples were trimmed of visible fat and nerves; they were cut into pieces (approximately 3×3 cm^2 of section and of 0.7 cm in thickness). Then, they were divided into two trials: the first trial was vacuum packaging, deep-frozen and stored at -40 ± 1 °C (Climas, Barcelona, Spain) and used as an external control of raw meat (untreated samples) for physical–chemical measurements (pH, color, and texture) and sensory analyses and to characterize the raw material. The second trial was subjected to a combined treatment of gaseous ozone, freeze-drying and modified atmosphere packaging (MAP) as described below.

2.2. Ozone treatments

After having prepared the breast samples, they were treated first with ozone. Ozonation assays were carried out in a 3 m^3 volume refrigerated chamber (Eurozon, Ecologyc 2000, Sestao, Vizcaya, Spain) to a continuous flow of ozone gas at 4 ± 0.5 °C and 90 ± 1% relative humidity. These conditions are important for the efficiency of the bactericidal effect of ozone (Kim, Yousef, & Chism, 1999). Ozone in form of gas was generated in situ utilizing a UV radiation using an ozone generator (Rilize, model 3060, Eurozon, Sestao, Spain). Ozone concentrations inside the chamber were monitored continuously by circulating air from the chamber through an ultraviolet absorption ozone gas analyzer (Ozomat MP, Anseros, Germany). The conditions of ozonation were described by Zouaghi (2011) for *Broiler* chicken meat and were the same in all treatments. The samples were exposed to gaseous ozone for 10 min with a dose of 0.6 ppm to reduce the initial levels of contamination (a reduction about 1.1 log cfu/g was observed in TAMB, LAB and *E. coli*. *Salmonella* spp. was not detected in any of the chicken samples).

2.3. Freeze-drying process

After ozone treatments and the microbial stability of the samples having been proved, they were dehydrated in a pilot scale freeze-dryer (Model Lyobeta 25, Telstar Industrial, S.L., Barcelona, Spain), and so impede the development of microorganisms and increase the shelf-life of the products.

The different parameters of the freeze-drying process assayed in this study were the same in all treatments and were the best conditions described in the research work of Babić et al. (2009). The initial a_w and moisture content of fresh chicken meat were about 0.984 ± 0.002 and 73.88 ± 0.06%, respectively. After lyophilisation, a significant decrease ($P < 0.05$) in those values was observed (0.131 ± 0.002 for a_w and 2.93 ± 0.06% for humidity).

2.4. Packaging

After ozone and freeze-drying treatment, all samples were individually packaged in low-O_2-permeable polystyrene/ethylvinylalcohol (EVOH)/polyethylene (PE) trays and heat-sealed using a low O_2-permeable cling film consisting of polyethylene terephthalate (PET)/EVOH/Polypropylene (PP) on the inside of the outer layer as a gas barrier, supplied by Ilpra Systems, S.L. (Barcelona, Spain). The trays had an oxygen transfer rate of less than 50 cm m^{-2} d^{-1} bar^{-1}, permeability to CO_2 less than 150 cm m^{-2} d^{-1} bar^{-1} and a water vapor permeability of less than 2.8 g m^{-2} d^{-1}. Samples were packaged using a packaging machine (Ilpra Termosaldatrici, España) with a sample/gas ratio of 1:3 (*w*/*v*). The untreated samples (frozen meat) were vacuum packed in impermeable plastic trays (type PA/PE 20/70,200 × 300) using a vacuum packaging machine (Model SAMMIC V-640, Gipuzkoa, Spain).

2.5. Modified atmosphere packaging experiments

In the present study, three different trials were carried out to evaluate the effect of modified packaging on the physicochemical and the sensory changes of ozonated dried chicken meat stored at different packaging atmosphere conditions, in order to choose the most suitable packaging conditions. The modified atmosphere gas conditions assayed are listed in Table 1.

The first set of trials (i) consisted of three experiments in which meat was packaged with three different oxygen concentrations (0, 20 and 30%O_2). This trial was planned in order to examine the influence of the effect of O_2 levels on the quality of MAP ozonated dried chicken. In the second trial (ii), the samples were packaged with four levels of CO_2 (20, 30, 40 and 50%CO_2), in order to evaluate the effect of carbon dioxide concentration on the quality of MAP ozonated dried chicken. Based on the results of trail (i) and trial (ii), the third trial (iii) was designed by using seven different compositions of $O_2/CO_2/N_2$ mixture. The concentrations of O_2, CO_2 and N_2 varied from one treatment to another, in order to determine the best O_2:CO_2 ratio needed to maintain the quality of ozonated freeze-dried chicken meat during 28 days of storage.

2.6. Storage conditions

After packaging, samples were coded and stored in a dark place at room temperature (21 ± 1 °C) for 28 days. The untreated samples (frozen meat) were kept at −40 °C until analyses. All samples were analyzed on days 1, 7, 15, 21 and 28 for physicochemical and sensory analyses. The 28 day period was the time allotted in order to verify the effectiveness of each MAP treatment where the degree of possible changes in hardness and juiciness was measured, because in preliminary studies they were the most affected by freeze-drying. A comparative study of those parameters of both the original fresh chicken meat and the treated meat was undergone.

Table 1
Experiments and different conditions used for ozonated freeze-dried chicken meat in modified atmosphere packaging.

Trials	Experiments	Packaging conditions		
		O_2 (%)	CO_2 (%)	N_2 (%)
Trial i	1	20	–	80
	2	30	–	70
	3	0	–	100
Trial ii	1	–	20	80
	2	–	30	70
	3	–	40	60
	4	–	50	50
Trial iii	1	10	30	60
	2	20	30	50
	3	30	30	40
	4	20	20	60
	5	30	20	50
	6	40	20	40
	7	20	10	70