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Valorization of industrial by-products: development of active coatings to reduce food losses

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ABSTRACT

An active coating based on soy protein, obtained as by-product from soy oil production, was used to extend the shelf-life of beef patties. On the one hand, the use of industrial by-products contributes to valorize by-products by preparing value added products. On the other hand, the extension of food shelf-life contributes to the reduction of food looses and could allow the use of lower amounts of packaging, reducing plastic waste. With this regard, some physicochemical and textural parameters of beef patties were analyzed in this study. The incorporation of the soy protein-based coating delayed food oxidation, prevented moisture loss and improved textural parameters of beef patties. Since the appearance and texture of food are very relevant aspects when purchasing food products, the improvement of these quality attributes showed in this study highlights the potential of using active coatings, such as the soy protein-based coatings analyzed in this work. In particular, their use would bring social benefits such as shelf-life extension and thus, reduction of food losses, but also the possibility of reducing the amount of packaging used to preserve food and the environmental and economical benefits associated with this reduction of packaging.

1. Introduction

The design of new products in the food industry requires a consideration not only from the materials science or engineering point of view, but also from the social, environmental, and economical point of view in order to develop sustainable products (Bertoluci et al., 2014). In the case of food products, packaging is necessary to protect food during storage and distribution from producer to consumer (Williams et al., 2008). Moreover, packaging plays an important role in the communication with consumers, being appearance one of the most important factors for food acceptance by consumers. With this regard, oxygen is responsible for many degradation processes in foods, such as lipid oxidation and thus, preventing this source of degradation is a crucial issue to improve food quality (Ayranci and Tunc, 2003). Although some oxygen availability is needed for respiration of living tissues, oxidative processes limit the shelf-life of food (Liu et al., 2010). When lipid oxidation occurs, adverse changes in fresh meat appear (Ladikos and Lougovois, 1990; O'Grady et al., 2001), so in view of the importance of these attributes for consumers, efforts to find ways of limiting lipid oxidation must be carried out.

Synthetic antioxidants have been widely used to reduce the degradation caused by oxygen; however, the potential health risks associated with these synthetic compounds have prompted strict regulations for their use in foods and consequently, the interest in the development and use of natural antioxidants agents as safer alternatives has markedly increased (Hayes et al., 2010; Moroney et al., 2013). In recent years, naturally occurring compounds derived from plant sources have been preferably employed in food products to increase their shelf-life since many plant-derived substances have antioxidant properties (Gupta and Abu-Ghannam, 2011; Siripatrawan and Noipha, 2012). The deleterious effect of oxygen on food may be delayed with the use of natural preservatives, such as ascorbic and citric acids (Bonilla et al., 2012; Nam and Ahn, 2003), since these antioxidants can scavenge free radicals and stop free radical chain reactions (Zhao et al., 2013).

Oxidation could be also reduced effectively by selecting coatings of limited oxygen permeability. The application of coatings on food products represents a new approach to solve or reduce the deterioration caused by oxygen on the quality of a wide range of

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products (López de Lacey et al., 2012). Coatings can act as a barrier to oxygen, which results in a better preservation of food quality. The type of product, as well as ambient conditions, determine the antioxidant effect of coatings (Mohan et al., 2012). Protein-based coatings generally provide a good barrier to oxygen transference (Elias et al., 2008). In the case of soy protein, it is an abundant protein source as by-product of soy oil production and its antioxidant activity has been demonstrated in model systems (Hayes et al., 2009; Shao and Tang, 2014; Zhang et al., 2010). Beef, because of its high content of unsaturated fatty acids, oxidizes rapidly and therefore, delaying lipid oxidation through the application of coatings is one approach to develop beef products with extended shelf life and superior product quality. As consumers are more health conscious, any strategy to extend food shelf-life should be preferably natural. In this context, the use of an abundant industrial by-product such as soy protein can offer a potential alternative as an active coating for food industry.

The effects of proteins such as soy protein on food are still not completely understood due to its complexity (Nishinari et al., 2014) and therefore, the analysis of the effects of this type of natural coatings to extend food shelf-life would be of great relevance. Since scientific literature contains little information regarding active coatings based on soy protein and applied on meat products, the objective of this work was to assess the effects of these coatings on the physicochemical and textural properties of beef patties stored in aerobic packages at 4 °C, as well as the social, economic and environmental implications of the use of active coatings.

2. Materials and methods

The materials used in this work were proteins obtained from by-products or wastes derived from food industries. Soy protein isolate (SPI), PROFAM 974, with 90% protein on a dry basis was supplied by Lactotecnia S.L. (Barcelona, Spain). The commercial bovine gelatin type A (bloom 200/220) was obtained from Sancho de Borja S.L. (Zaragoza, Spain). All proteins meet the quality standard for edible protein (1999/724/CE). Glycerol was food grade reactant obtained from Panreac (Barcelona, Spain) and it was used without any further purification.

2.1. Beef processing, coating and packaging

Fresh beef meat was supplied by Ballyburden Meat Processors, Cork, Ireland. Beef was minced twice through a plate with 4 mm holes (Model P114L, Talsa, Valencia, Spain). Minced beef was formed into patties (100 g portions) using a meat former (Ministeak burger maker, O.L. Smith Co. Ltd., Italy).

The edible coating solution was prepared by mixing SPI and 15 wt % gelatin (on SPI dry basis) in 100 ml distilled water. Solution was heated at 80 °C for 30 min under magnetic stirring. Then, 30 wt % glycerol (on SPI dry basis) was added and solution was maintained at 80 °C for other 30 min. This formulation was selected based on a previous work (Guerrero et al., 2011a,b). The final pH of the solution was 6.5. The solution was allowed to cool at 20 °C and the coating was applied with an air spray gun, using a nozzle cone (1.3 mm). In order to control thickness, coating time was fixed to 30 s, as reported in the method developed by Zhong et al. (Zhong et al., 2014; Leceta et al., 2015).

The fresh patties, non-coated and SPI-coated, were placed in polystyrene trays that were overwrapped with oxygen-permeable (6000–8000 cm^3/m^2/24 h at STP) polyvinyl-chloride film (Wrap Film Systems, Halesfield 14, Telford TF7 4QR, Shropshire, England). The packages were aerobically stored for up to 4 days at 4 °C and analyses were realized on days 0, 1, 2, 3 and 4.

2.2. Physicochemical analyses

Lipid oxidation was measured using the 2-thiobarbituric acid assay as described by Siu and Draper (1978). Minced beef samples (5 g) were homogenized for 2 min in 25 ml distilled water using an Ultra Turrax T25 homogenizer (Janke and Kunkel, IKA-Labortechnik, GmbH and Co., Staufen, Germany). Trichloroacetic acid (10%) (TCA) was added (25 ml) and the mixture shaken vigorously and filtered through Whatman No. 1 filter paper. In screw cap test tubes, 4 ml of clear filtrate was added to 1 ml of 0.06 M 2-thiobarbituric acid (TBA). The tubes were placed in a water bath and held at 80 °C for 90 min. The absorbance of the filtrate was measured on a UV–Vis spectrophotometer (Cary 300 Bio, Varian Instruments, CA, USA) at 532 nm against a blank containing all reagents (2 ml distilled water, 2 ml 10% TCA and 1 ml of 0.06 M TBA reagent). The malondialdehyde content of the samples was calculated using an extinction coefficient of 1.56 10^5 M^{-1} cm^{-1}. Results were expressed as 2-thiobarbituric acid-reactive substances (TBARS) in mg malondialdehyde (MDA)/kg beef.

The pH values for minced beef meat were determined by direct insertion of the probe into the meat using a digital pH meter (Mettler-Toledo GmbH, Schwerzenbach, Switzerland) with a penetration glass electrode.

The moisture loss (ML) was determined as described by Shon and Haque (2007). Samples (5 g) were weighed (m_i) and then oven dried at 102 °C for 18 h, cooled in a desiccator to room temperature and reweighed (m_d). The moisture content (MC) was calculated as:

$$MC(\%) = \frac{(m_i - m_d)}{m_i} 100$$

and ML values were calculated as follows:

$$ML(\%) = \frac{\left(MC_0 - MC_f\right)}{MC_0} 100$$

where MC_0 is the initial moisture content at day 0, and MC_f are MC values at days 1, 2, 3, and 4.

2.3. Textural analysis

Beef patties were cooked for texture analysis in a fan-assisted oven (Model 10 GN1/1, Zanussi Professional, Conegliano, Italy) at 180 °C for 10 min until an internal temperature of 71 °C was reached. Following cooking, patties were cooled for 1 h before testing.

Sample weights before (m_{fresh}) and after cooking (m_{cook}) and the differences in weights were recorded. Calculation for cooking loss was as follows:

$$CL(\%) = \frac{\left(m_{fresh} - m_{cook}\right)}{m_{fresh}} 100$$

Textural analysis was performed at room temperature with a Texture Analyzer 16 TA-XT2i (Stable Micro Systems, Surrey, UK). Samples were subjected to a two-cycle compression test using the 25 kg load cell. The samples were compressed to 40% of their original height with a 35 mm diameter cylindrical probe (SMSP/35 compression plate) and a cross-head speed of 1.5 mm/s. Force-time data from each test were used to calculate mean values for the textural parameters determined as described by Bourne (1978).

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