Food Chemistry 239 (2018) 544–550

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Application of chemometrics to assess the influence of ultrasound frequency, *Lactobacillus sakei* culture and drying on beef jerky manufacture: Impact on amino acid profile, organic acids, texture and colour

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ARTICLE INFO

Article history:
Received 6 February 2017
Received in revised form 13 May 2017
Accepted 20 June 2017
Available online 23 June 2017

Keywords:
Beef jerky production
Ultrasound
Lactobacillus sakei
Drying
Amino acids
Organic acids
Physicochemical properties

ABSTRACT

The effects of ultrasound (US) frequency, addition of *Lactobacillus sakei* culture and drying time on key nutritional (protein, amino acids, and organic acids) and physicochemical properties (texture and colour) of cultured and uncultured beef jerky were evaluated. Cultured and uncultured jerky samples were subjected to US frequencies of 25 kHz, 33 kHz and 45 kHz for 30 min prior to marination and drying. Principal component analysis demonstrated a significant effect of beef jerky processing conditions on physicochemical properties. Taurine content of jerky samples was found to increase with an increase in ultrasonic frequencies for cultured samples. No significant changes in colour values were observed for ultrasound pre-treated and control samples. Interactive effects of culture treatment, drying and ultrasonic frequency were observed. This study demonstrates that the nutritional profile of beef jerky can be improved through the incorporation of *L. sakei*.

1. Introduction

Jerky, also known as charque/charqui is derived from the term *Ch'arki* which means dried salted meat. Jerky is one of the most popular ready to eat nutritious traditional meat based product which can be prepared from almost any lean meat including beef, pork, poultry, or game. According to U.S. Department of Agriculture (USDA), jerky is classified as a non-perishable heat treated, shelf stable ready-to-eat meat product. Nowadays, a range of jerky products available consists of formed meat compared to traditional sliced whole meat which may be cured/uncured, dried, smoked/unsmoked, and air or oven dried. Commercially available jerky samples have low water activity in a range of 0.70–0.85 and have a moisture to protein ratio of ≤0.75 (Nummer et al., 2004).

Traditionally, jerky products are perceived as unhealthy. However, in recent years, consumption of jerky has increased significantly in Western meat-consuming countries. In a recent report of the Euromonitor International on sweet and savoury snacks in Ireland for 2015, it has been suggested that the air-dried protein product snack (beef jerky) was the "big breakout product". Additionally, IBIS World report highlighted that the beef jerky accounted for 79% jerky sales within USA in 2014. The growth of sweet and savoury snacks has been heavily influenced by the changing health attitudes. Moreover, jerky, as a protein source, is the main driver for its popularity. Typically chopped and formed beef jerky contains approximately 23.4% moisture, 33.2% proteins and 25.6% lipids depending on the formulation. Protein content as high as 81% has been reported for pork jerky (Ruiz-Ramírez, Arnau, Serra, & Gou, 2006).

Consumer demands for safe, minimally processed, nutritious, high quality with health benefits has led to a significant development for the production of jerky based products. The focus has been to improve nutritional quality of traditionally produced

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http://dx.doi.org/10.1016/j.foodchem.2017.06.124
0308-8146/

jerky samples. Numerous applications of novel ingredients including antioxidants (Kołożyn-Krajewska & Dolatowski, 2012; Udabage et al., 2010), stabilisers (Dobson, Sanozky-Dawes, & Klaenhammer, 2007), probiotics (Ruiz-Ramírez et al., 2006) and non-conventional technologies, such as irradiation (McLeod, Zagorec, Champomier-Vergès, Naterstad, & Axelsson, 2010), plasma (Hammes, Bantleon, & Min, 1990) have been reported to improve the physicochemical properties, nutritional and safety profiles of beef jerky.

Ultrasound (US) processing has been demonstrated to have the potential to improve food safety, extraction efficiency, emulsification/homogenization, crystallization, drying and fermentation processes (Achat et al., 2012; Chemat et al., 2017; Misra et al., 2017). This technique has shown an ability to save water, improve the reliability of processes, decrease emissions, improve product quality and enhance productivity compared to conventional processes (Li, Fabiano-Tixier, Tomao, Cravotto, & Chemat, 2013). US has shown promising applications in meat product manufacture (Purchas, Rutherfurd, Pearce, Vather, & Wilkinson, 2004; Ruiz-Ramírez et al., 2006; Troy, Ojha, Kerry, & Tiwari, 2016). For instance, US has been shown to improve the texture, salt diffusion rates, marination and water holding capacity of meat. For example, Smith (2011) reported a significant improvement in uptake of marination (91% water, 6% NaCl, 3% sodium tripolyphosphate) for 20 min US pre-treated chicken meat after 18 h of marination. Similar improvements in marination efficiency was reported for pork (Ozuna, Puig, García-Pérez, Mulet, & Cárcel, 2013) and chicken breast (Leal-Ramos, Alarcon-Rojo, Mason, Paniwnyk, & Alarjah, 2011).

Additionally, over the last years, the combination of US with traditional preservation techniques, such as fermentation has attracted much interest from both researchers and the food industry (Ojha, Mason, O'Donnell, Kerry, & Tiwari, 2017). In this line, *Lactobacillus* species have been established as important food-associated lactic acid bacteria, which are widely used as starter culture for industrial meat fermentation, and with great potential as a bio-preservative in meat products (Hammes et al., 1990; McLeod et al., 2010).

Therefore, taking on the technological trend to use non-conventional processing techniques in the meat industry, the objective of this study was to investigate the effect of US frequency, the addition of *L. sakei* culture and drying time on key nutritional (protein, amino acids, and organic acids) and physicochemical properties (texture and colour) of cultured and uncultured beef jerky samples by employing a reliable multivariate statistical strategy.

2. Material and methods

2.1. Sample preparation

Eye of the round (*Semitendinosus*) obtained from a local supplier (Dublin Meat Company, Blanchardstown, Co. Dublin, Ireland) was used in this study. Muscles were stored at 4 °C and were then cut into slices of similar size with a meat slicer (10 × 4 × 0.2 cm, L × W × H). The beef slices were cured in two different curing solutions: (I) Cultured, containing 70% water, *L. sakei* DSM 15,831 (10^4 cfu/mL), 1.5% salt, 1.0% sugar, 0.05% sodium nitrite and (II) Uncultured, containing 70% water, 1.5% salt, 1.0% sugar, 0.05% sodium nitrite (based on raw meat weight). The ingredients were thoroughly mixed, and samples from both cultured and uncultured groups were subjected to US pre-treatments at frequencies of 25 kHz (Elma Schmidbauer GmbH, Germany), 33 kHz (Jencons, (Jencons, Leighton Buzzard, UK) and 45 kHz (Elma Schmidbauer GmbH, Germany) for 30 min along with controls (no US treatment). US treatments were performed in US bath systems maintained at a temperature of 30 °C. All samples were subsequently cured for 18 h at 4 °C. All cured beef jerky slices were dried using a hot air dryer (Gallendkamp Plus II, Weiss Technik, UK) at a temperature of 60 °C for 4 h. Samples were withdrawn at drying times of 0 (after marination), 1, 2, 3 and 4 h and freeze dried prior to subsequent analysis.

2.2. Protein content and proteolysis index

Protein content of all the samples was determined using a LECO FP628 (LECO Corp., MI, USA) protein analyser based on the Dumas method according to the AOAC method 992.15 (1990). A sample extract of 0.25 g was used for protein estimation. Proteolysis index was determined as a percentage of the ratio between non protein nitrogen obtained by precipitation of proteins with trichloroacetic acid and total nitrogen obtained using the Dumas method (Ruiz-Ramírez et al., 2006).

2.3. Amino acid analysis

The amino acid analysis (free and total content) of beef jerky was carried out according to the procedures outlined by Gambuteanu and Alexe (2015) with the aid of JEOL JLC-500/V AminoTac™ amino acid analyser (JEOL Ltd., Herts, UK). Beef jerky samples were deproteinised to determine the free amino acids content using a trichloroacetic acid solution at 240 g/L for 10 min. Samples were centrifuged (14,400*g* for 10 min) and the supernatant was diluted with a sodium citrate buffer (0.2 mol/L; pH 2.2) and the content was diluted (1:2 v/v) with an internal standard (Norleucine) prior to injection. A $\lambda = 440$ nm was used to detect proline, while $\lambda = 570$ nm was used to detect the other amino acids. Aiming to assess the total amino acids content, beef jerky samples were hydrolysed using a 6 mol/L HCl solution at 110 °C for 23 h and all analyses were performed in triplicate.

2.4. Organic acid analysis

Organic acid analysis was performed according to the method outlined by Gupta, Jaiswal, and Abu-Ghannam (2013). Briefly, 1 g of jerky sample was mixed with 25 mL of distilled water, vortexed and centrifuged at 8720*g* for 10 min at 4 °C, whereas the fermented broth samples were directly centrifuged following the same conditions. The collected supernatant was filtered using 0.45 μm syringe filter and used for the determination of organic acids by HPLC. The HPLC analyses were carried out using the Waters Alliance HPLC (e2695 separation module) system equipped with W717 plus auto sampler, W486 UV detector and W410 differential refractometer detector connected in series. Chromatographic analysis was performed using an analytical Rezex ROA-Organic acid H^+ (8%) column (350 mm × 7.8 mm ID), fitted with a suitable guard cartridge (50 mm × 7.8 mm) (Phenomenex, UK). The analyses were carried out isocratically at a flow rate of 0.6 mL/min, employing 0.005 mol/L H_2SO_4 as mobile phase. A 20 μL aliquot was injected into a thermostatically controlled compartment set at 65 °C and the detection was carried out at 210 nm wavelength. The data acquisition and integration were performed using the Empower software package. The organic acids in the samples were identified by comparing the retention time and spectral data with that of standards, such as lactic acid and acetic acid (Sigma-Aldrich, Ireland).

2.5. Instrumental texture and colour

Textural properties of jerky samples from both cultured and uncultured group were measured using a Texture Analyzer (Model: TA-XT2i; Stable Microsystems, UK), with a 25 kg load cell and