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Physicochemical and sensory properties of yogurts containing sacha inchi (*Plukenetia volubilis* L.) seeds and β-glucans from *Ganoderma lucidum*

Ana-Milena Vanegas-Azuero and Luis-Felipe Gutiérrez[1]
Instituto de Ciencia y Tecnología de Alimentos (ICTA), Universidad Nacional de Colombia Sede Bogotá, Bogotá DC, Colombia, 111321

ABSTRACT

Dairy products have been widely used for adding various biomolecules with the aim of improving their functional properties and health benefits. In this study, the physicochemical properties and sensory acceptance of yogurts enriched with sacha inchi *(Plukenetia volubilis)* seeds (SIS) and β-glucans from *Ganoderma lucidum* (BGGL) were investigated. The angiotensin-converting enzyme–inhibitory activity of some yogurt samples was also evaluated. Yogurts were produced from reconstituted skim milk powder, and SIS (4% wt/wt) and BGGL were added at different concentrations (0–1.5% wt/wt). The fermentation kinetics were not affected by the enrichment process. The addition of SIS and BGGL significantly increased the contents of protein, fat, carbohydrates, ash, total solids, aspartic acid, serine, arginine, glycine, threonine, tyrosine, and alanine. α-Linolenic (49.3%) and linoleic (32.2%) acids were the main fatty acids found in the enriched samples, whose values were about 50- and 25-fold higher than those of the control yogurt. The textural parameters (firmness, consistency, cohesiveness, and index of viscosity) of the enriched yogurts were significantly lower than those of the control samples during the whole storage period. All enriched yogurts showed a sensorial acceptance higher than 70% by untrained panelists. The angiotensin-converting enzyme–inhibitory activity of some selected yogurt samples ranged between 36 and 59%. These results indicate that SIS and BGGL could be used as natural ingredients for improving the nutritional value of yogurt and fermented milks.
Key words: yogurt, sacha inchi, β-glucan, *Ganoderma lucidum*

INTRODUCTION

Yogurt is recognized as a healthy food throughout the world due to its beneficial effects on human health. Although it contains natural compounds of high nutritional value, such as proteins, peptides, vitamins (principally B_{12}, riboflavin, and D), and minerals (mainly Ca, P, I, and K), there is great interest in the enrichment of this dairy product to further improve its nutritional value and health benefits because it is considered a foodstuff for daily consumption (Singh et al., 2012; Williams et al., 2015). Nowadays, probiotics are the main bioactive compounds added to yogurt. However, efforts are being made to enrich yogurt with other functional ingredients originating from dairy and nondairy sources. Among them, different types of fibers, phytosterols, polyphenols, stanols, peptides, isoflavones, β-glucans from various sources, essential fatty acids, whey protein concentrate, minerals, and vitamins have been investigated (Özer and Kirmaci, 2010). It is worth mentioning that the incorporation of any functional ingredient into a dairy product such as yogurt will have an effect on its final cost. Consequently, the dairy industry needs to establish cost-effective strategies and processes to achieve the development of functional products at the lowest cost possible, even if these products could have the potential to mitigate some diseases, promote health, and reduce health care costs.

Essential fatty acids (from the families of n-3 and n-6) have gained special attention as functional ingredients because of their wide range of health benefits, including brain development and reduced risk of cardiovascular diseases, certain types of cancer, and inflammatory diseases (Simopoulos, 2002). Because milk is relatively poor in essential fatty acids, the development of dairy products rich in essential fatty acids could contribute to increasing the intake of these biomolecules in the population. Fish oils are the main natural sources of long-chain n-3 fatty acids. However, their incorporation into fermented milks may confer negative effects on their texture, sensory properties, and shelf life (Isanga and Zhang, 2009; Sabeena Farvin et al., 2010). The addition of oils rich in n-3 in the form of microcapsules (Martín-Diana et al., 2004; Sabeena Farvin et al., 2010; Tamjidi et al., 2012), emulsions (Chee et al., 2005) and nanoemulsions (Lane et al., 2014; Boye, 2015) has been successfully used to circumvent these problems.

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[1]Corresponding author: lfgutierreza@unal.edu.co

The enrichment with short-chain n-3 fatty acids from vegetable oils (Dal Bello et al., 2015), seeds, nuts, and fruit pulps (do Espírito Santo et al., 2010; Ozturkoglu-Budak et al., 2016) has also been investigated, although from a nutritional and functional point of view their effects are not exactly the same as those of the long-chain n-3 fatty acids contained in fish oils.

β-Glucans are polysaccharides of D-glucose monomers linked through β-glycosidic bonds, present in cereal crops (especially barley and oats) and some mushrooms. These compounds are considered bioactive compounds due to their biological activities, including anti-cancer, anti-inflammatory, and immune-modulating properties (Zhu et al., 2016). Moreover, β-glucans are among the main fractions of the dietary fiber of some grains, such as oats and barley (Ciron et al., 2010). Various studies suggest that the addition of β-glucans at concentrations up to 0.5% to fermented milks has no negative effects on their quality, whereas the enrichment at higher concentration levels may reduce the fermentation rate, increase the viscosity, and lead to syneresis due to thermodynamic incompatibility between the β-glucans and the milk proteins (Singh et al., 2012; Lazaridou et al., 2014; Sharafbafi et al., 2015).

The aim of this work was to evaluate the physicochemical properties and the sensory acceptance of yogurts enriched with sacha inchi seeds (**SIS**), which are rich source of n-3 and n-6, tocopherols, phytosteroles, phenolics compounds, protein of high nutritional value, and dietary fiber; Gutiérrez et al., 2011; Chirinos et al., 2013) and β-glucans from *Ganoderma lucidum* (**BGGL**; Ganogen, Progal-BT, Medellín, Colombia), a commercial ingredient obtained by submerged cultivation of *Ganoderma lucidum*, an edible mushroom used as a traditional medicine, pharmaceutical, and nutraceutical agent in various Asian countries for the treatment of several human diseases, including hypertension, hypercholesterolemia, and various types of cancer (Bishop et al., 2015). Moreover, because milk fermentation by lactic acid bacteria has shown to release angiotensin-converting enzyme (**ACE**)–inhibitory peptides, the ACE-inhibitory activity of some selected yogurt samples was also investigated.

MATERIALS AND METHODS

Materials

The SIS were kindly supplied by a local grower from Fusagasugá (Cundinamarca, Colombia). The seeds were manually selected by discarding those presenting physical damage. Then, they were vacuum packaged in polyethylene bags and stored at −40°C until use. Commercial β-glucans (Ganogen), produced by submerged cultivation of *Ganoderma lucidum*, were kindly supplied by Progal-BT (Medellín, Colombia). The starter culture Yomix 205 LYO (*Streptococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Lactobacillus acidophilus*, and *Bifidobacterium lactis*) was generously provided by DuPont Colombia (Bogotá). The skim milk powder (~2 g of fat/L) and sucrose were purchased in local markets. All reagents and standards used in the analytical determinations were of analytical grade and purchased from Sigma-Aldrich (St. Louis, MO).

Methods

The protein, ash, moisture, and fat contents of the SIS and BGGL were determined using methods 950.36, 923.03, 935.29, and 922.06, respectively (AOAC International, 2012). The content of total carbohydrates was calculated by difference. The fatty acid composition of the SIS was determined by GC as described by Gutiérrez and Belkacemi (2008).

The β-glucans of the commercial Ganogen (BGGL) were extracted according to the method proposed by Dong et al. (2012) and analyzed in terms of their glycosidic composition by means of size exclusion chromatography HPLC (Superose 12-column 10 × 300 mm evaporative light scattering detector; GE, Amersham, UK), and GC-MS analyses of their per-*O*-trimethylsilyl derivatives [Agilent (Santa Clara, CA) 7890A GC interfaced to a 5975C Mass Selective Detector using an Agilent DB-1 fused silica capillary column (30 m × 0.25 mm i.d.)], following the procedures recommended by Merkle and Poppe (1994) and York et al. (1985).

Thermogravimetric analyses (**TGA**) were performed using a TGA 1 (Mettler-Toledo, Columbus, OH). Samples of 5 mg of BGGL were weighed in an aluminum pan and heated at 10°C/min to 550°C (Kumar, 2010). Data were analyzed using thermal analysis software (STARe Evaluation; Mettler-Toledo).

Transform infrared (**FT-IR**) spectra were recorded in transmission mode on a Nicolet iS10 FT-IR spectrometer (Thermo Scientific, Waltham, MA) in the range of 400 to 4,000 cm^{-1} by the coaddition of 20 scans at a resolution of 8 cm^{-1}. The FT-IR analyses were carried out at room temperature using potassium bromide pellets containing about 0.5% of the BGGL samples (Gutiérrez et al., 2012).

SIS Conditioning

The SIS were hand shelled, washed with tap water, and then roasted at 160 ± 5°C in an oven for about 2 h until the bitter taste disappeared. The roasted seeds