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Review

Flavor of lactic acid fermented malt based beverages: Current status and perspectives

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ABSTRACT

Background: Although several research studies have described potentialities of lactic acid fermented cereal beverages as functional beverages, their market and industrial applications are quasi non-existing. Poor sensory quality, low acceptance, and lack of production technology seem to be the challenges. Sensory characteristics, commonly described as sour, sweet, cereal-like, and malty, are not always regarded as positive by consumers and represent therefore an important hurdle for their acceptance. Neither their aroma composition has been studied in depth for overall aroma understanding, nor has an attempt for sensory profile improvement been done. Aroma type and quantity might depend on several factors like starter culture, substrate, and fermentation process.

Scope and approach: In this review, we discussed the potential of cereal malt wort as a precursor medium for aroma compound formation during lactic acid fermentation; sensory characteristics and aroma-active compounds of lactic acid fermented cereal beverages are also described; strategies that can be exploited for flavor improvement are proposed with focus on existing technologies. Case studies based on existing products are included for technological innovation in order to meet increasing consumer's demands for new tastes.

Key findings and conclusions: Further works on characterization of aroma compounds, elucidation of key aroma compounds that contribute to the overall aroma, flavor impact of the interactions aroma - organic acids, consumer's needs investigation, lactic acid bacteria starter culture selection and fermentation process management will provide significant advances towards the flavor improvement of cereal beverages for a promising market.

1. Introduction

The increasing society quest for healthier and natural foods, new tastes and food ingredients is oriented, in beverage sector, towards non-alcoholic and functional beverages with preference towards those containing no additives and preservatives (Roethenbaugh, 2007; Vartanian, Schwartz, & Brownell, 2007). The global market for functional foods in general and functional beverage in particular has steadily increased over the past decade all over the world. Furthermore, nondairy functional beverages are in demand due to vegetarianism, milk cholesterol content, and lactose intolerance (Fortitech, 2011; Granato, Branco, Cruz, Faria, & Shah, 2010; Granato, Branco, Nazzaro, Cruz, & Faria, 2010). Thus, one of the challenges facing food industries is to innovate in order to adapt to changing consumer's demands and maintain market leadership. Investigations on new fermented foods are the emerging trends to be applied in the food Technology. Beverages already available on the market and consideration of existing resources such as cereals, combined with current technologies and processes are valuable bases for further innovation.

Cereals have recently retained a lot of attention as raw material for non-alcoholic and functional beverages production. High fiber, whole or multi-grain containing beverages represented in 2012 and 2013 the greater part of the better-for-you new foods and beverages with desirable benefits (IRI, 2014). Desirable benefits derived from cereals are their high nutritional value and bioactive compound content (Adil, Wani, Masoodi, & Gousia, 2012; Alvarez-Jubete, Arendt, & Gallagher, 2009; Fardet, 2010; Sarwar, Sarwar, Sarwar, Qadri, & Moghal, 2013; Thompson, 1994). Lactic acid bacteria (LAB)

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have been extensively used since many decades for the production of cereal based beverages. Their tremendous potentialities as cell factories for the delivery of functional biomolecules in cereal based beverages to fulfill broad range of consumers life style nutrition have been explicitly highlighted (Hassani, Procopio, & Becker, 2015; Singh, Rehal, Kaur, & Jyot, 2013; Waters, Mauch, Coffey, Arendt, & Zannini, 2013).

Lactic acid fermented malt based beverages are non-alcoholic, with low pH value (3.5–4.5) and produced by the fermentation of cereals, cereal substrates or blends by LAB strains. Available lactic acid fermented cereal beverages include yogurt-like cereal functional beverages and traditional cereal fermented beverages (Corbo, Bevilacqua, Petruzzi, Casanova, & Sinigaglia, 2014; Müller-Auffermann, Thormann, Hutzler, & Jacob, 2013) (Table 1). Barley, wheat, oat, rye, rice, sorghum, quinoa and amaranth were demonstrated as potential growth medium substrate for LAB. Furthermore, malted cereal substrates promote LAB growth and aroma compound generation better than non-malted cereals (Charalampopoulos, Pandiella, & Webb, 2003; Coda, Rizzello, Trani, & Gobbetti, 2011; Gebremariam, Hassani, Zarnkow, & Becker, 2015; Kedia, Wang, Patel, & Pandiella, 2007; Salmerón, Rozada, Thomas, Ortega-Rivas, & Pandiella, 2014; Salmerón, Thomas, & Pandiella, 2015; Zannini et al., 2013).

Despite the acknowledged health benefits of lactic acid fermented cereal beverages, they are poorly accepted by consumers. The most important attributes for functional food choice was taste in 59% of cases whereas nutritional aspects were considered as important in only 36% of cases (Azzurra & Paola, 2009). In the same line, consumers requested an improvement of the flavor of lactic acid fermented cereal based beverages as the most important attribute (Yu & Bogue, 2013). Therefore, the key issue for future viability and success of these beverages on the market is consumer acceptance (Granato, Branco, et al., 2010) which is driven by the flavor and nutritional aspects. Their flavor is generally characterized as sour, malty, sweetish, cereal-like, and worty-like (Coda et al., 2011; Gebremariam et al., 2015; Salmerón, Rozada, et al., 2014; Salmerón et al., 2015). Due to consumer diversity to sour food acceptance, the sourness on account of intrinsic organic acids may also impact sensory perception. Recently, a cereal beverage fermented with a *Lactobacillus plantarum* strain was better accepted by consumers. It was tentatively attributed to acetaldehyde content (Salmerón et al., 2015). Flavor improvement is therefore a key step for the development of these beverages. Considerations on their overall aroma composition are thus very crucial although little attention has been given.

Aroma-active compound groups were identified in lactic acid fermented cereal beverages. Quantitation studies on acetaldehyde, acetone, acetoin, and ethanol revealed concentrations of acetaldehyde and acetoin higher than their odor detection threshold (Salmerón et al., 2015). There are no studies yet that described their contribution to the flavor or which attempt to enhance the aroma profile. Furthermore, attractive aroma compounds such as esters were quasi absent.

Aroma compound formation in lactic acid fermentation involves different pathways, precursors and enzymes (Gänzle, Vermeulen, & Vogel, 2007; Smid & Kleerebezem, 2014). The occurrence and activity of enzymes, esterases for instance, are strain dependent in LAB (Kim et al., 2013; Liu, Holland, & Crow, 2004; Rojas, Gil, Piñaga, & Manzanares, 2003). In addition, enzyme activity rate are well-known to rely on fermentation parameters such as temperature, pH, substrate, and cofactors availability. On the other hand, environmental stresses improved the formation of particular aroma compounds in sourdough lactic acid fermentation (De Angelis, Bini, Pallini, Cocconcelli, & Gobbetti, 2001; Serrazanetti, Guerzoni, Corsetti, & Vogel, 2009; Serrazanetti et al., 2011). Therefore, aroma type and concentration may be determined by substrate composition, starter culture and environmental conditions and process.

This review presents research advances on lactic acid fermented cereal beverages focusing on sensory characteristics and aroma-active compounds. The potential of malt wort as a basis for lactic acid fermentation and source of aroma compound precursors is discussed as well. Existing limitations and future research strategies for flavor improvement of lactic acid fermented cereal beverages are proposed, especially for new design of processes, selection of more suitable LAB and strain consortia, or by optimization of raw materials.

2. Some examples and case studies for technological innovation

Innovation in lactic acid fermented malt based beverages is oriented towards production of probiotic beverages which follows the general wellness claim trend. Table 1 lists existing commercially available and traditionally produced lactic acid fermented cereal beverages. Commercially available beverages are made from probiotics LAB strains and intended to be consumed as probiotic beverages. Sometimes fruit extracts are added to enhance the flavor as with Jovita Probiotisch beverage. Mageu was successfully fermented with probiotic strains of *Lactobacillus rhamnosus* and *Lactobacillus acidophilus* and the sensory acceptance was similar to that of traditionally produced beverage (Nyanzi, Jooste, Abu, & Beukes, 2010). Fortification of Mahewu with iron for nutritional value increase was successfully developed (Salvador, 2015). Obiolor is associated with health properties such as attenuation of high-fat diet, dyslipidemia, protein oxidation, lipid peroxidation as observed in rats, and antioxidant properties (Ajiboye et al., 2016). Grainfields Wholegrain probiotic Liquid® is rich in probiotics, vitamins, amino acids and enzymes.

Further innovation trend could be directed towards the development of beverages with health related benefits such as gluten-free, low-cholesterol and high bioactive compound content that could be suitable for diverse nutrition lifestyles such as veganism, vegetarianism, low cholesterol nutrition, and people suffering from nutrition related non-communicable diseases and cardiovascular diseases. A case study is the development of a high content cereal based beverage produced from pseudo cereal quinoa, lupine (*Lupinus albus* L.), and mesquite (*Prosopis chilensis (Mol.) Stunz*) with a final protein content of 1.36% that was acceptable for drinking (Cerezal Mezquita, Acosta Barrientos, Rojas Valdivia, Romero Palacios, & Arcos Zavala, 2012). This beverage could be a suitable product for vegan nutrition lifestyle or high protein nutrition lifestyle. However, the high content of lupine in flatulescence oligosaccharides and phytate should be a serious concern. Lactic acid fermentation by selected LAB strains could not only reduce the content with non-significant change on the net protein ratio (Camacho et al., 1991) but also improve the flavor for a more appealing beverage. Besides the richness of lupine in plant protein, it has also functional properties such as hypoglycemic effect and body weight reduction as observed in humans and rats (Bertoglio et al., 2011; Capraro et al., 2014). Therefore, the production of a protein rich beverage based on malt wort, lupine and lactic acid fermentation will be an innovation in cereal based beverage production. However, the flavor being the most important criteria for functional food choice before nutritional aspect (Azzurra & Paola, 2009), a focus should be given to the flavor profile.