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Dietary fibre in fermented oat and barley β-glucan rich concentrates

Adele M. Lambo *, Rickard Öste, Margareta E.G.-L. Nyman

Applied Nutrition and Food Chemistry, Center for Chemistry and Chemical Engineering, Lund University, P.O. Box 124, SE-221 00 Lund, Sweden

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Abstract

The ability of different lactic acid bacteria to influence the physicochemical characteristics (content, viscosity and molecular weight) of dietary fibre in β-glucan-rich barley and oat concentrates was investigated. The cultures used were *Lactobacillus acidophilus* and the exopolysaccharide producing strain *Pediococcus damnosus* 2.6, together with the yoghurt culture, V2 (a mixture (1:1) of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus salivarius* subsp. *thermophilus*). Two methodologies, one including filtration and another centrifugation-dialysis, to quantify the dietary fibre, were compared. The centrifugation-dialysis method generally gave significantly ($P < 0.05$) higher values than the filtration method (for example, 79.8 g/100 g DW versus 59.6 g/100 g DW for the total fibre in the native barley fibre concentrate) with the exception of soluble barley fibres. The insoluble fibre content was found to decrease after fermentation (58.8 g/100 g DW to 39.0/37.0 g/100 g DW in barley and 26.0 g/100 g DW to 4.5/3.0 g/100 g DW in oats as analysed by the centrifugation-dialysis method). The soluble fibre in the barley fibre concentrate was apparently not affected by fermentation, while contents and maximum viscosities of the soluble fibre in oat fibre concentrates decreased after fermentation. However, the molecular weight was apparently not affected.

Keywords: Oats; Barley; Polysaccharides; Dietary fibre; β-glucans; Physicochemical characteristics; Viscosity; Molecular weight; Fermentation; Lactic acid bacteria; Cereals

1. Introduction

The beneficial effects of healthy diets on quality of life and on the cost-effectiveness of health care has prompted the food industry to face the challenge of developing new food products with special health-promoting characteristics. Meeting this challenge involves the identification of new sources of nutraceuticals, as well as other nutritional and natural materials with the desirable functional characteristics. Barley and oats are examples of such sources and could be good bases for functional food products.

Cereals are an important source of dietary fibre, contributing to about 50% of the fibre intake in western countries (Nyman, Björck, Siljeström, & Asp, 1989). The hemicellulosic polysaccharides of rye and wheat are composed mainly of pentosans (arabinoxylans), whereas those in oats and barley are composed mainly of β-glucans (Selvendran & Verena, 1990). Both barley and oats have been reported to be effective in lowering total serum- and LDL-cholesterol in humans and animals, the effect being attributed to the content of β-glucans (Behall, Scholfield, & Hallfrisch, 1997; Bell et al., 1999; Federal register, 1997; Maier, Turner, & Lupton, 2000; McIntosh, Whyte, McArthur, & Nestel, 1991). Furthermore, a study on hypercholesterolaemic men, for 5 weeks, has shown that a milk-like oat product that contributed with 3.8 g/d of oat β-glucans significantly reduced total serum- and LDL-cholesterol by 6% (Onning et al., 1999). Similarly, in a study by McIntosh et al. (1991), it was demonstrated that plasma LDL-cholesterol concentrations were lowered by 7% in mildly hypercholesteroaemic men, who consumed 8 g/d of barley β-glucans for 4 weeks.

Recent studies have shown that oat-based media could be suitable for the growth of lactic acid bacteria (LAB) and also for the formation of microbial or exopolysaccharides (EPS) (Mårtensson, Öste, & Holst,

* Corresponding author. Tel.: +46-46-222-4768; fax: +46-46-222-4532.
E-mail address: adele.lambo@inl.lth.se (A.M. Lambo).

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2002a; Mårtensson et al., 2002b). This is interesting because EPS are capable of improving the texture and viscosity of the final product (Ricciardi, Parente, & Clementi, 1994) and may also improve both sensory and nutritional properties. Some of the cultures used in the dairy industry have also been described as promoters of ropiness or mouth-feel, because of their texture-enhancing properties (Sutherland, 1998). Moreover, yoghurts with EPS-producing strains have demonstrated less shear-thinning behaviour in comparison with yoghurt made with non-EPS producing strains (Sutherland, 1977). This structural property would probably give rise to a new generation of *in situ* produced thickeners, which could decrease the need of stabilisers in yoghurt (Cerning, 1995). In addition, a study conducted by Nakajima, Suzuki, Kaizu, and Hirota (1992), in which rats were fed a ropy milk product containing a phospho-polysaccharide, revealed a reduction in serum lipids.

Lactic acid bacteria are also capable of producing EPS with a β-glucan structure, as described by Dueñas-Chasco et al. (1997), who isolated straight-chained β-(1 → 3) glucans with β-(1 → 2) glucose monomers linked to the interior chain from *Pediococcus damnosus* 2.6, that is β-glucans with somewhat different structure from those found in oats and barley that contain linear β-glucans with alternating (1 → 3) and (1 → 4) linkages. The physiological effects of this LAB produced EPS may depend on their ability to resist degradation by gastrointestinal enzymes, and thus behave like a type of dietary fibre. However, nothing is known about their physicochemical properties or physiological effects.

The aim of the present study was to investigate how different lactobacilli strains could affect the content of "dietary fibre components", especially the β-glucans, and their physicochemical characteristics (viscosity and molecular weight) in barley and oat fibre concentrates. Further, as there may be a degradation of dietary fibre polysaccharides to smaller fragments during fermentation, these may be soluble in 80% ethanol and as a consequence there will be loss of fibre (Johansson, 1987) when using one of the conventional fibre methods (Asp, Johansson, Hallmer, & Siljestöm, 1983; Englyst, Cummings, & Wood, 1987; Prosky, Asp, Schweizer, deVreis, & Furda, 1988; Theander, Åman, Westerlund, Andersson, & Pettersson, 1995). Therefore another methodology was also used, including centrifugation and dialysis instead of precipitation with ethanol and filtration.

2. Materials and methods

2.1. Bacterial strains

Lactobacilli strains with optimal growth temperatures of 28 and 43 °C were used. The EPS-producing strain, *Pediococcus damnosus* 2.6 (Pd 2.6), was obtained from the collection at the University of San Sebastian (Spain, UPV). The strain was stored at −80 °C in de man Rogosa Sharpe (MRS) broth (De Man, Rogosa, & Sharpe, 1960) containing 25% (v/v) glycerol. The commercial yoghurt culture V2 was a 1:1 mixture of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus salivarius* subsp. *thermophilus* (Visby Tønder nder, Denmark). *Lactobacillus acidophilus* (La5) was obtained from Christian Hansen A/S, Hørsholm, Denmark. V2 and La5 were stored at −80 °C according to the recommendation of the manufacturer. These two cultures were chosen because V2 is the starter culture commonly used in Sweden and La5 is known to improve aroma and acidity in the final product.

2.2. Sample preparation and fermentation procedure

Native oat and barley fibre concentrates, with dry matter contents between 8% and 10%, were obtained from Ceba Foods AB (Lund, Sweden). Oats had been treated enzymatically, ultrafiltrated and dialysed as previously described (Oste, 1999). Barley was treated in a similar manner. The substrates glucose or sucrose (1%, w/v) were added to the cereal fibre concentrates prior to inoculation with V2/Pd 2.6 and V2/La5, respectively. After heat-treatment at 90 °C for 5–10 min, the cereal fibre concentrates were cooled to fermentation temperature (28 or 37 °C for V2/Pd 2.6 and V2/La5, respectively) and then inoculated. The fermentations were performed over a period of about 20 h. A 0.02% portion of the V2 and La5 cultures was used as inoculum. Pd 2.6 inoculate (5% v/v) was taken from a fresh (20-h incubation) pre-inoculum. The pre-inoculum medium was cereal-based and inoculated with 5% of an exponentially growing Pd 2.6 in MRS broth (Merck, Darmstadt, Germany) and then incubated for approximately 20 h at 28 °C. The final pH of the fermented products was 4.0 ± 0.3. All samples were lyophilised using a Labconco lyphlock 12 freeze-dry system and milled to a particle size of less than 0.3 mm in a Cyclotec mill (Tecator AB, Höganäs, Sweden). Moisture content was determined by drying to constant weight at 105 °C.

2.3. Analytical methods

2.3.1. Analytical steps

A simplified flowchart of the quantification and characterisation steps used is shown in Fig. 1.

2.3.2. Protein

The nitrogen was assayed by the Kjeldahl procedure (Kjeltec System 1003, Tecator AB, Sweden) according to the manual. Protein was calculated as $N \times 6.25$.