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Short communication

Nutritional value of *Chlorella vulgaris*: Effects of ultrasonication and electroporation on digestibility in rats

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Abstract

Three processed products derived from the green algae *C. vulgaris* were investigated: (1) spray-dried only (S-DA); (2) spray-dried and electroporated (ES-DA); (3) spray-dried; ultrasonicated treated (US-DA). A nitrogen-balance study was performed. Male growing Wistar rats, housed separately in metabolism cages, were fed the three algal products as the sole protein source at 150 mg N per 100 g of body weight. A control group of rats was fed with casein at a level to give the same protein nitrogen intake. The coefficients of total intestinal tract apparent crude protein digestibility for the different *C. vulgaris* products were: S-DA = 0.47 ± 0.127% (mean ± S.D.), ES-DA = 0.44 ± 0.075%, US-DA = 0.57 ± 0.137%. Protein efficiency ratio was 1.4 ± 0.3, 1.0 ± 0.5 and 2.1 ± 0.3, respectively. N-balance was 41.86 ± 32.8 mg, 31.3 ± 17.3 mg and 66.7 ± 30.1 mg, respectively. The biological value was 93 ± 9.5%, 93.6 ± 10%, and 101 ± 5%, respectively. The coefficient of total intestinal tract apparent crude protein digestibility and biological value of *C. vulgaris* was enhanced by ultrasonic treatment and reduced by electroporating, thus ultrasonication may be a helpful technological process in practical processing of green algae in food industry.

Keywords: *Chlorella vulgaris*; Nutritional value; Protein digestibility; Rats

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1. Introduction

Chlorella vulgaris is a unicellular micro-alga that is ubiquitous in freshwater environments. The nutritional value of *C. vulgaris* was initially determined in 1950s–1960s (Lubitz, 1963). Since then *C. vulgaris* has also been shown to have immune-modulating and anti-cancer properties (Justo et al., 2001; Konishi et al., 1985, 1990, 1996; Morimoto et al., 1995; Noda et al., 1996; Singh et al., 1999; Tanaka et al., 1984, 1986; Yasukawa et al., 1996). Feeding micro-algae to elderly people or animals has been demonstrated to protect from age-dependent diseases, particularly cardiac hypertension or hiperlipidemia (Okamoto et al., 1978; Sano and Tanaka, 1987; Sano et al., 1988; Tsuchida et al., 2003).

The nutritive value of outdoor or indoor cultured *C. vulgaris* is of interest to the food industry, especially in countries where the weather conditions do not allow massive culture of higher plants. Nevertheless, first results of such studies were equivocal, depending upon the technological process used to treat the algal mass. Different thermal processes applied in order to destroy the robust cell wall, which restricts access of digestive enzymes to the intracellular components, also lead to destruction of amino acids and/or active substances within the algal cells (Komaki et al., 1998; Lin, 1969; Lubitz, 1963; Saleh et al., 1985). In order to facilitate the access of digestive enzymes, and thus to enhance the nutritional potential of the cells, three different technological processes were applied in this study and their influence on the *C. vulgaris* protein digestibility and utilization was investigated in a study undertaken in rats.

2. Materials and methods

2.1. C. vulgaris

The unicellular green algae *C. vulgaris* biomass was obtained from the Institute for Cereal Processing Ltd. (IGV), Nuthetal-Rehbruecke, Germany, where it had been cultivated in a closed photobioreactor PBR 4000 using sunlight (Pulz et al., 2000). For feeding studies on animals, three different types of algae have been used—spray dried (referred to subsequently as untreated), electroporated and ultrasonic treated.

2.2. Electroporation

The algal biomass was injected by a pump into the treatment cell with a delivery rate of 120 L/h (model HIS, self-made, TU-Berlin, Germany). The electrode gap in the cell was 2 cm. A constant electrical field strength of 3 kV/cm was applied, this caused a specific energy input of 7 kJ/kg algal biomass but no significant increase in temperature. After electroporation the *C. vulgaris* biomass was spray dried.

2.3. Ultrasonic technique

C. vulgaris biomass (start temperature of 20 °C) was treated using an ultrasonic device (model UP 400S, Dr. Hielscher GmbH, Teltow, Germany). The pressure varied between