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Development of powdered food with the addition of *Spirulina* for food supplementation of the elderly population

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ABSTRACT

The elderly are prone to developing nutritional deficiencies of vitamins, minerals, and proteins as well as energy. The addition of *Spirulina* biomass to food is of interest because of the microalga's nutritional content. Therefore, this study sought to develop chocolate flavor shake-type powdered food, enriched with *Spirulina.* The chemical composition of the products was analyzed, and they were subjected to sensory testing and shelf life estimation. Food developed presented a mean 42% ($w \cdot w^{-1}$) protein and 46% ($w \cdot w^{-1}$) carbohydrates content. The average acceptance rates were 7.68 and 7.77, for shakes with and without *Spirulina*, respectively. The shelf life was estimated at 19 months for the product with incorporated biomass and 24 months for product without *Spirulina.* Sensory analysis showed that the addition of *Spirulina* in foods was well accepted by the target public. Products with added microalgal biomass can provide energy and protein and can contribute to the elderly population's nutritional requirements.

Industrial relevance: The preparation of food products for specific population groups pose major challenges for the food industry. These processes involve large investments in research, but tend to generate competitive advantages for the investing companies. One of the groups that deserve special attention are the elderly, who may present a number of specific nutritional deficiencies that must be supplied by diet. Within this scenario, the enrichment products for seniors with *Spirulina* becomes very interesting, because it makes food a source of protein and carbohydrates, as well as providing a number of dietary bioactive compounds, essential fatty acids and vitamins.

1. Introduction

The aging process can change the nutritional status of elderly due to reduced appetites and increased nutritional needs. In elderly people, the risk of nutritional deficiencies is very common and can cause malnutrition or worsen a state of frailty and contribute to the development of morbidities. Some aging problems can be associated with low intake of protein, minerals, and vitamins (Mingioni et al., 2016; Skully, 2014; Van der Zanden, Van Kleef, de Wijk, & Van Trijp, 2015).

The high incidence of protein deficiency among elderly is one of the main concerns for this portion of population (Brownie, 2006; Wolfe, Miller, & Miller, 2008). The increased protein intake has been related to a range of health benefits in elderly because proteins are essential components of all cells of the body, and it helps to maintain the immune system. Between the benefits for protein intake for elderly, it has been related to the faster rehabilitation for hip fractures (Schurch et al., 1998), the increased lean body mass and strength (Borsheim et al., 2008), and the lowered risk of becoming frail (Beasley et al., 2010).

Aging is also associated with the insufficient intake of micronutrients, such as vitamins and minerals. As the overall micronutrient deficiency leads to global nutritional deficiency, the intake of foods rich in vitamins and minerals is also recommended. So the potential for the development of enriched functional foods for elderly is ever increasing (Skully, 2014; Van der Zanden et al., 2015).

The microalga *Spirulina* is widely acknowledged for its high protein content (60–70 g/100 g). It is a source of vitamins, especially vitamin B12, and pro-vitamin A, minerals (mainly iron), and γ-linolenic acid (Belay, 2013; Habib, Huntington, Parvin, & Hasan, 2008). Also, the biomass of *Spirulina* contains c-phycocyanin and phenolic compounds, which are responsible for antioxidant activity, as both *in vitro* and *in vivo* studies have shown (Fernández-Rojas, Hernández-Juárez, & Pedraza-Chaverri, 2014; Kepekçi, Polat, Çelik, Bayat, & Saygideger, 2013).

Some foods have been developed with the biomass of *Spirulina* (Figueira, de Crizel, Silva, & de Salas-Mellado, 2011; Lemes, Takeuchi, de Carvalho, & Danesi, 2012; Morais, Miranda, & Costa, 2006; Rodríguez De Marco, Steffolani, Martínez, & León, 2014). However, to date, specific products for the elderly with the addition of this biomass have not been developed. In addition, there are few studies in the literature addressing

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the development of products with nutritional properties for elderly people (Manders, de Groot, & Blauw, 2009; Wouters-Wesseling et al., 2003).

Studies demonstrate that microalgal biomass consumption may lead to important therapeutic effects such as anti-cancer (Hirahashi et al., 2002; Kurd & Samavati, 2015) a hypolipidemic effect (Ponce-Canchihuamán, Pérez-Méndez, Hernández-Muñoz, Torres-Durán, & Juárez-Oropeza, 2010) and protection against diabetes and obesity (Anitha & Chandralekha, 2010). Due to these advantages, *Spirulina* biomass is a nutritionally important raw material for the development of products for the elderly.

The sensory acceptance response for developed foods, when they are tested per consumers who can notice the differences between products, is one of the most important aspects (Kim, Dessirier, van Hout, & Lee, 2015) to ensure the quality of products that may be made available to the market consumer. Another important factor in the development of foods is the determination of shelf life to ensure that the consumer obtains good quality products. Mathematical models have been developed to estimate the shelf life of foods with low water activity, based on a relationship between the moisture absorption of the product, the storage environment, and the packaging's barrier property (Alves, Bordin, & Garcia, 1996; Sirpatrawan, 2009).

Given the above food for the elderly should be attractive and take into account the nutritional needs of this population. Therefore, it is convenient to develop special foods that provide the nutrients that the elderly require, are easy to prepare and have a pleasant taste. The objective of this study was to develop chocolate flavor shake-type powdered food, enriched with *Spirulina*.

2. Materials and methods

2.1. Development of the foods

The selection of ingredients was carried out based on the nutritional needs of the elderly population. For the development of formulations, preliminary tests were performed with varying proportions of ingredients. The ingredients were weighed using an analytical scale (Model F4 2104 N, Bioprecisa, Brazil) and mixed in a Y type mixer (Model TE-201/10, Tecnal, Brazil).

The components used in the formulation were maltodextrin, concentrated soybean protein, isolated whey protein (WPI), oatmeal, collagen, inulin, guar and xanthan gums, aroma identical to natural chocolate, cocoa, tricalcium phosphate, acesulfame potassium, sucralose, a mix of minerals (iron, zinc, copper, iodine, selenium, manganese, fluoride, molybdenum, chromium, magnesium, potassium, and sodium), and vitamins (A, D, B1, B2, PP, B5, B6, B12, C, E, H, K, and folic acid). The product that was developed with *Spirulina* received an additional 750 mg/100 g of microalgal biomass (the concentration was set so as not to alter the homogenization of the product).

Spirulina sp. LEB 18 biomass was produced in the pilot plant of the Biochemical Engineering Laboratory, on the shores Mangueira Lagoon (33° 30′ 13″S and 53° 08′ 59″ W) in the city of Santa Vitória do Palmar, Brazil (Morais et al., 2009). The biomass was ground in a ball mill (Model Q298, Quimis, Brazil) and sieved to improve its solubility.

2.2. Percentage composition and sensory analysis

Developed shakes were evaluated for moisture, ash, fiber, protein, and lipids, according to the methodology described by AOAC (2000). The method of 3.5 DNS (Miller, 1959) was used to determine the carbohydrate content, with prior acid hydrolysis.

The sensory evaluation of the shakes with and without *Spirulina* and of a similar product found on the market (commercial shake) was carried out using tests of acceptance and purchase intent. To evaluate the acceptance of the products by the target consumers, the hedonic scale of nine points was used: point 1 corresponded to "extremely dislike" and point 9 corresponded to "enjoyed it very much." The panelists' buying attitude was assessed by using a five-point scale from "certainly would not buy" (point 1) to "certainly would buy" (point 5) (Meilgaard, Civille, & Carr, 1999).

2.3. Estimated shelf life of products

The shelf life of the developed food was estimated according to the mathematical model described in Eq. (1). The model relates the increase in moisture of the product, using its moisture sorption isotherm, to the water vapor transmission rate (WVTR) of the packaging (Alves et al., 1996):

$$SL = \frac{m_d \cdot RH}{100A \cdot WVTR} \int_{M_o}^{M_c} \frac{dM}{\frac{RH}{100} - a_w(M)} \quad (1)$$

where

SL shelf life estimate (days);
m_d dry mass of product (g);
RH relative humidity of the storage environment (%);
WVTR water vapor transmission rate of the packaging ($g_{H2O} \cdot m^{-2} \cdot day^{-1}$);
a_w (M) water activity of the product as a function of moisture content (moisture sorption isotherm of the product);
M_o and M_c initial moisture and critical moisture of the product (%, $w \cdot w^{-1}$), according to AOAC (2000);
A packaging area (m^2).

2.3.1. Water vapor transmission rate (WVTR)

High-density polyethylene packaging (HDPE) (Model R30, InjePlast) was characterized according to the water vapor transmission rate using the ASTM E96/E96-05 method (2005). This method is based on the increase of mass of anhydrous calcium chloride ($CaCl_2$) stored in packaging. Thus, the packaging was placed in a desiccator with a saturated $BaCl_2$ solution (RH = 90%) at 30 °C. The $CaCl_2$ mass gain was determined on a daily basis until the rate was constant. The WVTR ($gH_2O/m^2/day$) of packaging was calculated according to Eq. (2), and G/t (gH_2O/day) was the angular coefficient of the linear adjustment of the mass gain curve as a function of time (t), and A (m^2) was the permeation area of the packaging.:

$$WVTR = \frac{(G/t)}{A} \quad (2)$$

2.3.2. Moisture sorption isotherm and critical moisture

The samples were placed in desiccators containing saturated salt solutions (CH_3COOK, $MgCl_2$, K_2CO_3, NaBr, NaCl, and $BaCl_2$) with RH between 22% and 90% in order to determine the moisture sorption isotherm. The desiccators were maintained at 30 °C until stabilization of the mass of the samples.

After this period, the equilibrium moisture contents (M) were determined according to AOAC (2000), for each relative humidity condition. The sorption isotherm experimental data were adjusted using the Halsey equation (Eq. (3)), where C_1 and C_2 are adjustment constants (Halsey, 1948):

$$a_w = \exp\left(-\frac{C_1}{M^{C_2}}\right) \quad (3)$$

The critical moisture of the products was established based on changes that have occurred during storage at 30 °C, at the different relative humidity conditions.